Background paper on aquaculture research

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Background Paper on Aquaculture Research

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The contents of this background paper are the responsibility of the authors.

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1. Summary

The Board of MISTRA established in 2012 a Working Group (WG) on Aquaculture to provide the Board with background information for its upcoming decision on whether the foundation should invest in aquaculture research. The WG included Senior Advisor Axel Wenblad, Sweden (Chairman), Professor Ole Torrissen, Norway, Senior Advisory Scientist Unto Eskelinen, Finland and Senior Advisory Scientist Alfred Jokumsen, Denmark.

The WG performed an investigation of the Swedish aquaculture sector including interviews with a range of stakeholders within aquaculture research, farming organisations, authorities, NGOs and the Ministry of Rural Affairs.

The term aquaculture corresponds to the Swedish term Vattenbruk. Aquaculture is the cultivation of fish, shellfish or plants in fresh water (FW) or sea water (SW). Aquaculture has become the fastest growing food producing sector currently producing totally about 80 million tonnes accounting for close to 50 % of all aquatic food destined for the global human consumption.

The Swedish aquaculture production currently includes about 11,000 tonnes rainbow trout in FW and SW, 1,100 tonnes arctic char (FW), 90 tonnes eel (FW), 1,500 tonnes mussels (SW) and a few tonnes of crayfish altogether corresponding to a total value of SEK 328 million in 2011. Further about 1,000 tonnes of fish and crustaceans were produced for restocking as well as about 3 million fry of salmon and trout were released into rivers.

Swedish aquaculture research was overall assessed to be of very high quality and highly acknowledged at international level. However, integration of the research issues with the main stakeholders in the aquaculture sector needs focus; i.e. integration of the political frameworks, regional administrations, the aquaculture producers and the research groups on aquaculture.

A closer connection and dialogue between the stakeholders may be facilitated through the regional aquaculture centres interconnected through the National Competence Centre for Aquaculture, and the National Aquaculture Council being established. These structures may create a common and focused platform for cooperation on research and education, exchange and transfer of knowledge from research to aquaculture practice. Further, integration of biological and technological research combined with education and training of skilled professionals as well as authority staff dealing with aquaculture is strongly called upon.

Hence, a strong integration of the stakeholders within the aquaculture sector is assessed to be an important platform for a trans-disciplinary research and development program for strategic and efficient development of Swedish Aquaculture.

Sweden has large potentials for aquaculture due to the availability of vast water resources of good quality (both marine and fresh water), a high veterinary status and generally well developed public infrastructure. Swedish aquaculture has the potential to develop into a green business producing environmentally sustainable healthy food with low ecosystem and climate impact. Swedish import of aquaculture products may be reduced by increased domestic production. Further Swedish aquaculture may be a driving force in the development of employment, infrastructures and improvement of economic and social conditions in rural areas. Swedish

aquaculture has the potential to contribute significantly to food security. It is therefore important that aquaculture becomes an integrated part of the food production system, i.e. being accepted as an equal food producing sector in line with the agricultural sector.

Innovative development of Swedish aquaculture requires production systems with minimal environmental impact, e.g. recirculation technology, efficient feeds and waste management. Although the nutrient-poor hydropower dams in northern Sweden may tolerate nutrient load the strategy for the required development of Swedish aquaculture has to include technologies and strategies to minimize the environmental impact, in particular to the Baltic Sea. Swedish aquaculture may develop to be an environmental service, which may be exported.

The governmental policy on aquaculture should reflect the conclusions of the official report *Det växande vattenbruket* and the strategy *Svenskt vattenbruk – en grön näring på blå åkrar, Strategi 2012–2020*. Implementing the strategy will require a real management of aquaculture that secures the balance between responsibility for the environment and development of aquaculture production.

For a significant and powerful Swedish aquaculture to develop, strong and committing policy instruments should be coordinated and managed. This means that the strategy for aquaculture needs to be followed by a long term focused research policy on aquaculture and responsibility for putting it into force as well as availability of adequate funding from national and international sources (e.g. EMFF, research councils, EU, Nordic and BONUS). Finally, the financial sector should be made more confident with aquaculture to facilitate investments in aquaculture.

The integration of environmental, economic and social sustainability is essential for the development of a dynamic Swedish aquaculture industry. Research should include basic and applied aquaculture research integrated with resilience science and take a food systems approach considering relevant aspects of the food chain between farm and fork (e.g. producers, food industry, retail and consumers).

Aiming to enable a progressive change of the Swedish aquaculture sector the Working Group recommends that MISTRA establishes a research program on aquaculture including:

1. Global ecosystem aspects of aquaculture production including diversification, production systems, species, products, etc.
2. Environmental efficient production with trapping of solid waste and balanced nutrient management (recirculation technology, waste heat/green energy/integrated production systems).
3. Policy instruments: legislation, economic incentives, socioeconomic dimensions, labelling, organic farming and certification schemes.

2. Svensk sammanfattning

MISTRA's styrelse gav 2012 en arbetsgrupp i uppdrag att ta fram en bakgrundsrapport om vattenbruk. Rapportens syfte är att utgöra ett underlag för styrelsen vid beslut om framtida forskningssatsningar. Arbetsgruppen har bestått av seniorrådgivare Axel Wenblad, Sverige (ordförande), professor Ole Torrissen, Norge, seniorrådgivare Unto Eskelinen, Finland, och seniorrådgivare Alfred Jokumsen, Danmark. Arbetsgruppen har undersökt den svenska vattenbrukssektorn och intervjuat ett brett urval av aktörer och intressenter inom forskning, branschen, myndigheter och ideella organisationer. Arbetsgruppen har även träffat företrädare för Landsbygdsdepartementet.

Vattenbruk innebär odling av fisk, skaldjur eller växter, antingen i sötvatten eller i saltvatten. Vattenbruk är den snabbast växande formen av matproduktion i världen med för närvarande en årlig produktion av ungefär 80 miljoner ton, vilket utgör närmare hälften av den totala mängden fisk, skaldjur och vattenväxter som används för mänsklig konsumtion.

Den svenska vattenbruksproduktionen uppgick år 2011 till ungefär 11 000 ton regnbåge (i söt- och saltvatten), 1 100 ton röding (i sötvatten), 90 ton ål (i sötvatten), 1 500 ton musslor (i saltvatten) och några få ton kräftor, vilket tillsammans motsvarade ett värde av 328 miljoner kronor. Vidare producerades ungefär 1 000 ton sättfisk (inklusive kräftor). Ungefär 3 miljoner lax- och havsöringsungar sattes ut i älvar.

Arbetsgruppens bedömning är att den svenska vattenbruksforskningen håller mycket hög kvalitet och att den i hög grad är internationellt erkänd. Forskningsfrågorna behöver dock i större utsträckning knytas till användarnas behov. Det innebär samverkan mellan beslutsfattare, myndigheter, branschen och forskarna.

De regionala vattenbrukscentrumen (för närvarande Väst och Norr), det Nationella kompetenscentrumet för vattenbruk och det nationella vattenbruksrådet, som är under bildande, bör kunna bidra till en närmare dialog mellan olika parter, t.ex. genom att skapa en gemensam plattform för samverkan om forskning och utbildning och för utbyte och överföring av kunskap. Det behövs också en integrering av biologisk och teknisk forskning i kombination med utbildning av yrkesverksamma inom branschen och av handläggare på myndigheter som hanterar vattenbruksfrågor. Aktiv medverkan av alla berörda parter är en förutsättning för ett transdisciplinärt forskningsprogram med målet att strategiskt och effektivt utveckla det svenska vattenbruket.

Sverige har goda förutsättningar för vattenbruk genom en lång kust och många sjöar, hög veterinärstandard och en generellt väl utbyggd infrastruktur. Svenskt vattenbruk har möjligheter att utvecklas till en grön näring som producerar ekologiskt hållbar och nyttig mat med liten miljö- och klimatpåverkan. Importen av odlad fisk och odlade skaldjur kan minskas genom ökad inhemsk produktion. Svenskt vattenbruk skulle kunna bli en motor för nya jobb, utbyggd infrastruktur och förbättrade ekonomiska och sociala förhållanden på landsbygden. Svenskt vattenbruk skulle också i högre grad kunna bidra till livsmedelsförsörjningen. Det är därför viktigt att vattenbruket blir en integrerad del av livsmedelssektorn och accepteras som jämställt med t.ex. jordbruket.

För att förnya och utveckla det svenska vattenbruket krävs produktionssystem med minimal miljöpåverkan, t.ex. recirkulationsteknik och effektiv foder- och avfallshantering.

Även om de näringsfattiga kraftverksdammarna i norra Sverige tål viss näringsbelastning måste en strategi för att utveckla vattenbruket innehålla teknik och strategier för att minska miljöpåverkan. Det gäller i synnerhet Östersjön. Svenskt vattenbruk skulle kunna utvecklas till att erbjuda lösningar på miljöproblem, t.ex. bortförsel av näring. Ett svenskt kunnande på det området bör kunna exporteras.

Slutsatserna i vattenbruksutredningens betänkande *Det svenska vattenbruket* och i strategin *Svenskt vattenbruk – en grön näring på blå åkrar, strategi 2012–2020* bör återspeglas i regeringens politik för vattenbruk. För att genomföra strategin krävs ett vattenbruk som kan hantera balansen mellan miljö och produktion.

För att det svenska vattenbruket ska kunna växa och utvecklas behövs effektiva styrmedel. Strategin för svenskt vattenbruk behöver åtföljas av en långsiktig och fokuserad forskningsagenda och ett ansvar för att genomföra denna samt tillgång till finansiering från nationella och internationella källor (t.ex. de statliga forskningsråden, den Europeiska Fiskerifonden, EU:s ramforskningsprogram, nordisk finansiering och Östersjöprogrammet BONUS). Slutligen behövs finansiärer som är villiga att investera i vattenbruk. Finanssektorn måste övertygas om vattenbrukets ekonomiska potential.

En integrering av ekologisk, ekonomisk och social hållbarhet är nödvändig för att få till stånd ett dynamiskt vattenbruk i Sverige. Forskningen måste inkludera både grundläggande och tillämpade frågeställningar och integreras med forskning om resiliens. Forskningen bör dessutom ha en systemansats och inkludera relevanta aspekter av hela livscykeln från uppfödning/odling till tallrik (t.ex. odlingsförutsättningar, fodertillverkning, detaljhandel samt konsumentbeteende).

Arbetsgruppen rekommenderar MISTRA att etablera ett forskningsprogram om vattenbruk. Programmets syfte ska vara att bidra till förnyelse och utveckling av svenskt vattenbruk. Forskningsprogrammet bör inkludera följande:

1. Globala ekosystemaspekter på vattenbruk inklusive diversifiering, produktionssystem, arter, produkter etc.
2. Miljömässigt effektiv produktion med uppsamling av föroreningar och minimerade utsläpp av näringsämnen (recirkulationsteknik, system för användning av spillvärme, integrerade produktionssystem).
3. Styrmedel: lagstiftning, ekonomiska styrmedel, socioekonomiska dimensioner, miljömärkning, ekologisk odling och certifieringssystem.

3. Assignment and the Planning Process

The aim of MISTRA (The Foundation for Strategic and Environmental Research) is to support research of strategic importance for solving strategic environmental problems as well as contributing to the development of a sustainable society. The foundation shall promote the development of robust research environments of the highest international class, including interdisciplinary research programmes that will have a positive impact on Sweden's future competitiveness. The potential for practical implementation of the research results in companies, authorities etc. shall be realized as far as possible.

The Board of MISTRA decided in June 2011 to initiate planning of new research initiatives. Aquaculture was one of the areas selected as a potentially new research area and hence action was taken to investigate the basis for establishment of a program on Aquaculture.

To provide the basis for a decision a working group on aquaculture was designated in August 2012 and chaired by Senior Advisor Axel Wenblad, Sweden. The other members of the group were Professor Ole Torrissen, Institute of Marine Research, Norway, Senior Advisory Scientist Unto Eskelinen, Finnish Game and Fisheries Research Institute, Finland and Senior Advisory Scientist Alfred Jokumsen, Technical University of Denmark, DTU Aqua, Denmark. Specifically Alfred Jokumsen was asked to lead the evaluation of the Swedish research on aquaculture as well as the preparation of this report.

4. Terms of Reference

Background

The perspective of all MISTRA research invests is to secure a good living environment and development of a sustainable society. The Board of MISTRA has selected aquaculture as a potentially new research initiative. The total value of farmed food fish amounted to SEK 328 million in 2011. The same year, the number of persons employed in Swedish aquaculture was estimated at 392. The dominating aquaculture species in Sweden is rainbow trout. A new official strategy for Swedish aquaculture concludes that although aquaculture is a small business in Sweden today there is a large potential for growth. Aquaculture research is also a rather small business in Sweden scattered over several universities and institutes. Gothenburg University and the Swedish University of Agricultural Sciences (SLU) have taken the initiative to establish a National Competence Centre for Aquaculture.

Task

The main task of the Working Group was to provide the Board of MISTRA with background information for its upcoming decision on whether the foundation should invest in aquaculture research.

The Working Group should:

- Describe current Swedish aquaculture research and perform a state of the art review putting Swedish research into an international context
- Make an overview of the Swedish aquaculture industry in a global context
- Briefly compare aquaculture to other food production systems
- Briefly discuss the bottlenecks for Swedish aquaculture development
- Critically analyse the arguments for why MISTRA should invest in aquaculture research (cf. MISTRA's statutes), and
- Suggest scope and focus of a new MISTRA research initiative (if recommended).

The Working Group should consult with researchers, representatives for the industry and other stakeholders.

Deadline

A final report should be submitted to MISTRA no later than 1 March 2013.

5. What is aquaculture?

Aquaculture is defined as farming of aquatic organisms in inland and coastal areas, involving intervention in the rearing process to enhance production (FAO, 2012a). More generally speaking aquaculture is the cultivation of fish, shellfish (including oysters, mussels, clams and crustaceans) or plants (seaweed, algae) in fresh or sea water. The term aquaculture corresponds to the Swedish term Vattenbruk.

Aquaculture has become the fastest growing food producing sector currently producing totally about 80 million tons accounting for about 50 % of all aquatic food destined for the global human consumption, i.e. the global aquaculture production is at the same level as the supplies from wild fisheries (FAO, 2012a).

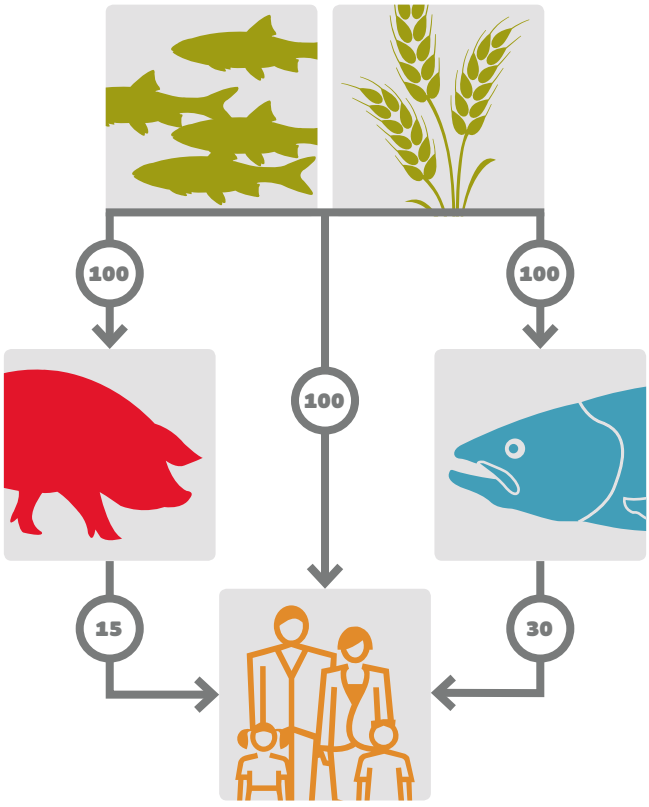
However, aquaculture also includes production of fish and shellfish for restocking in fresh or sea water.

6. Aquaculture and other food production systems

Oceans cover more than 70 % of our planet. While plant production in the sea is at the same magnitude as the terrestrial plant production, we get only slightly above 1 % of our daily energy intake from sea food. The reasons for this disparity are multiple. However, the low utilization of marine resources opens huge potentials for increased food production through cultivation of the oceans. This may substantially contribute to closing the gap in food supply caused by increasing world population and prosperity.

Fish are much more efficient in utilizing feed resources than land living animals. This is due to the fact that fish are poikilothermic animals (their body temperature following the environmental temperature) while land-living animals, e.g. mammals, birds, are homoeothermic keeping a constant and fixed body temperature, which is more energy requiring. Additionally, due to buoyancy fish do not use much energy to keep in the water column, while land-living animals have to use energy for standing up and move. Fish are also more efficient in terms of higher slaughter yields due to low skeleton weights, and they excrete NH_3 while terrestrial animals excrete mainly urea or uric acid, which leave more energy in the excretion products. As an example fish has a utilization of the feed energy that is double of that in pigs, cf. figure 1.

FIGURE 1 Salmonids utilize the energy double as efficient as the most efficient farmed mammals (pigs).
FROM ÅSGÅRD ET AL., 1999.



Aquaculture production has only minor emissions of greenhouse gasses compared to production of cow, pig or poultry as well as fish production requires much less water, i.e. a climate friendly way of producing food (SOU, 2009).

Fish feed for aquaculture production has historically been based on marine resources (fish meal and fish oil), but increasing demand of fish meal and particularly fish-oil rich in omega-3 fatty acids for human use as well, has led to markedly increasing prices and a reduced availability for the aquaculture sector. Therefore ingredients of plant origin are increasingly contributing to fish feed compositions. Ongoing research is investigating potential new marine ingredients (mussel meal, algae etc.) as components in fish feed. Use of marine sources primarily as ingredients in fish feed has the potential to contribute to a closed nutrient cycle in areas where eutrophication is a problem.

Aquaculture has apparently not been regarded as an integrated part of the Swedish food production system, which is a challenge for the development of Swedish aquaculture (SOU, 2009).

7. Swedish Aquaculture in an EU and a global context

In 2010, the world aquaculture production was 60 million tonnes of fish and crustaceans and 20 million tonnes of aquatic plants (FAO, 2012b). For comparison capture fisheries provided 90 million tonnes, i.e. the share from aquaculture was about 47 % of the total aquatic production, and excluding aquatic plants, the share from fish and crustaceans was about 35 %. The world human consumption was estimated to about 18 kg per capita per year. Globally, aquaculture is the fastest growing food producing sector – outpacing population growth, e.g. the global production of fish, crustaceans and aquatic plants increased by about 5 % per year from 2001 to 2010 (FAO, 2012b,c). Excluding plants the annual increase was a little lower (4.8 %). The growth is highest in Asia, which accounts for more than 89 % of the global production, while EU growth in the sector is stagnant (EU, 2012a).

World-wide capture fisheries and aquaculture provide the daily living basis for about 45 million people and provide more than 180 million jobs (FAO, 2012c) along the whole value chain. Employment in aquaculture is increasing at a faster rate than world population growth and now accounts for ¼ of the total number of workers in the fisheries sector (FAO, 2012c).

Due to the increasing importance of aquaculture in the global food security, it has been identified as one of the five pillars, where potential exists for long-term growth and creation of jobs in line with the objectives of the Europe 2020 strategy. This statement was included in the recently adopted document by the EU Commission: *Blue Growth opportunities for marine and maritime sustainable growth* (EU, 2012a).

More than 90 % of the aquaculture producers in the EU are SMEs, providing about 80,000 jobs (EU, 2012a). Aquaculture has the potential to grow by providing high-value products to the consumers requesting fresh, reliable and sustainable or organically produced food. Moreover, aquaculture can help rural development in particular coastal communities alleviating fishing pressure and thus helping to preserve fish stocks (EU, 2012a).

In the EU lack of accessible aquaculture space, competition in the global market and administrative constraints, in particular concerning licensing procedures as well as financing for investment in aquaculture, are amongst the challenges to growth of European aquaculture. Sustainable aquaculture must also consider potential impacts on wild fish stocks and water quality, including national and EU environmental protection policies (EU, 2012a).

As a part of the Common Fisheries Policy (CFP) reform as well as the *Blue Growth* paper giving specific priority to aquaculture (2012a), the Commission aims to stimulate sustainable aquaculture growth through non-binding strategic guidelines, long term national strategic plans and exchange of best practice and optionally including integrated multi-trophic aquaculture. The administrative practices, especially in licensing, are aimed to be improved as well as the development is expected to be supported financially by the proposed European Maritime and Fisheries Fund (EMFF). The future Horizon 2020 programme for research and innova-

tion is also expected to play an important role in unlocking the growth potential of European aquaculture (EU, 2011, EU, 2012a).

Sweden has the lowest production of rainbow trout among the Scandinavian countries and competition from e.g. Norwegian salmon may be one reason for that. Actually, based on a stable domestic market Finnish and Norwegian investors with aquaculture knowledge and experience have moved into farming of rainbow trout in Sweden (SOU, 2009). The import of seafood products from Norway amounted to about 72,000 tonnes (Norges Sjømatråd, 2013) corresponding to about SEK 2.3 billion in 2011 (*www.ssb.no*).

The EU financial support to the Swedish aquaculture sector is through the European Fisheries Fund (EFF), which contributes 50 % of the budget of approved projects and the remaining 50 % are supposed to be financed by national Swedish funds. However, the national co-financing for aquaculture projects has not been able to match the EU contributions (SOU, 2009).

8. Status of Swedish aquaculture

The development of farming of salmonids in Sweden became speeded up by the "compensation farming" linked to the use of hydro power and the establishment of dams obstructing the migration of salmonids to their upstream spawning grounds (Kiessling, 2013). The hydro power plants were committed to compensate the missing recruitment of fry by producing fish for releasing downstream and restocking the upstream water bodies. The hydro-power industry established their own research institute – *Laxforskningsinstitutet* in Älvkarleby – and developed the basic farm techniques and became as well linked to the establishment of the feed company EWOS in Södertälje.

Swedish aquaculture today includes farming of fish (rainbow trout, arctic char, eel) in about 150 farms, crayfish and mussels (totally about 50 farms), and especially in the rural areas (Jordbruksverket, 2012a). In 2011 the Swedish aquaculture production of consumption fish was about 12,000 tonnes, i.e. about 11,000 tonnes rainbow trout in FW and SW, 1,100 tonnes arctic char (FW), 90 tonnes eel (FW), 1,500 tonnes mussels (SW) and few tonnes (uncertain figures) of crayfish (mainly signal crayfish and some noble crayfish) – corresponding to a total value of about SEK 325 million, cf. figure 2. In addition to that about 1,000 tonnes of fish and crustaceans were produced for restocking (Jordbruksverket, 2012b).

For compensatory purposes about 3 million fry of salmon and trout were released, mainly in rivers running into the Baltic.

It is noticed that the production of consumption fish (rainbow trout and arctic char) has increased significantly from 5,000 tonnes in 2007 to about 12,000 tonnes in 2011, and that there are big regional variations in production per farm, i.e. from a few tonnes per farm around Stockholm, Jönköping, Kalmar, Skåne up to

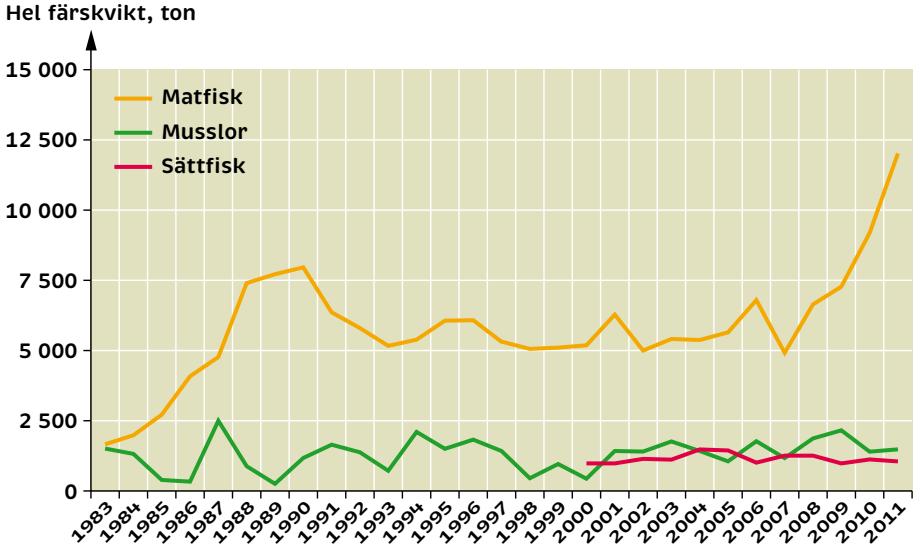


FIGURE 2 Production in Swedish aquaculture 1983–2011.
FROM JORDBRUKSVERKET, 2012B.

100–1,000 tonnes per farm in Västra Götaland, Värmland, Dalarna, Västernorrland, Jämtland (Vattudalen), Norrbotten and Västerbotten. Further, there has been a shift in production volume from sea water to fresh water – apparently for environmental reasons (Jordbruksverket, 2012b).

The farming units for the FW production consist of net cages in lakes, ponds, various types of tanks as well as a few recirculation systems. The production of rainbow trout in cages in fresh water has been the most profitable (SOU, 2009). There has been a significant increase in the production of arctic char from 347 tonnes in 2007 to 1,100 tonnes in 2011. Crustaceans are exclusively farmed in ponds. Mussels are produced on lines hanging down into SW from anchored ropes.

About 30 % of the rainbow trout were produced in net cages in SW, i.e. about 3,000 tons, mainly in 9 farms at the North East coast (Gävleborgs, Västernorrlands, Västerbottens and Norrbottens County). Further south about 250 tonnes were produced in 12 farms (Jordbruksverket, 2012b).

Good health conditions and low occurrence of diseases are crucial for all aspects of aquaculture production, i.e. welfare, low mortality, productivity, food quality etc. Therefore, the main aim of the Swedish Health Control Program is to keep Sweden free of the most serious contagious diseases of fish and shellfish (both in aquaculture and in wild populations). Hence the program should secure a unique health status in Sweden and an opportunity to produce specific pathogen free fish for consumption, restocking and fisheries.

An increased aquaculture production in Sweden including recruitment of new species calls upon crucial precautions to sustain the health status in Sweden, which includes prevention of disease transmission between wild fish and farmed fish as well as transmission of diseases across the borders. Therefore, updated education and training of people working in the aquaculture industry is of utmost importance, i.e. improved effectiveness and competence of national as well as regional authorities, but also further cooperation and communication within the aquaculture industry to have farmers being more aware of preventing fish diseases.

About 400 people were employed by the Swedish aquaculture production in 2011 (Jordbruksverket, 2012b). However, limited formal education opportunities have been available. Though, at *Yrkeshøgskolan* in Jämtland a one year higher vocational education has been introduced.

The investments in Swedish aquaculture amounted to totally SEK 58 million from 2000–2006, which were shared by SEK 14 million from EU, SEK 3 million from other public bodies and the remaining SEK 41 million were private investments (SOU, 2009). Further SEK 22 million have been allocated for funding of various aquaculture projects (e.g. breeding). The investments were mainly in rural areas (Västerbottens and Jämtlands County). The median investment per farm was about SEK 0.5 million.

Until 2009 the EFF 2007–2013 programme has funded aquaculture activities by SEK 31 million with 50 % from EU and 50 % from the Swedish government. Half of this funding was allocated for farming of mussels and oysters (SOU, 2009). To the public funding should be added the private contributions.

Swedish aquaculture production is regulated according to the environmental legislation as an "environmentally hazardous activity" in the sense that aquaculture activities may imply risk of environmental impact. To initiate any aquaculture activity you need to describe the environmental impact of your activity, including the impact on humans, animals, land and water etc. Environmental permission is required by the County Administrative Board (Länsstyrelsen) if more than 40 tonnes of feed is expected to be used annually. At lower consumptions a notification to the local environmental authorities is sufficient.

The permission to run an aquaculture activity is also regulated according to the ordinance of fishery and aquaculture and shall be applied for at the County Administrative Board. Additionally, the Board of Agriculture and Fish Health Authori-

ties are involved (SOU, 2009). The environmental legislations seem very strict and complicated and are making challenges to get permissions to and running aquaculture production. Extensive documentation for applications, public participation and wide-scale permit considerations make the process technically heavy. Further, the Swedish fish farmers pay proportionally very high inspection fees compared to agricultural farmers. However, some discretion may facilitate the process in some counties. The validity periods of the permits are quite long and the allowed production volumes relatively high. Due to this the administrative costs are relatively lower for big producers than for small producers. The legal regulation systems of the Baltic Sea Region states (including Sweden) are studied in the AQUABEST project (Paavola & al. 2012).

Further, bureaucracy seems to be a major challenge for Swedish aquaculture development due to the many authorities involved:

- The Board of Agriculture
- National Food Agency
- The Swedish Agency for Marine and Water Management
- National Veterinary Institute
- County Administrative Boards (*Länsstyrelser*)
- Municipalities

Recently (July 2012) a new strategy for Swedish aquaculture was launched: *Svenskt vattenbruk – en grön näring på blå åkrar, Strategi 2012–2020* (Jordbruksverket, 2012c). The strategy has been developed in cooperation with a broad range of stakeholders (universities, organisations, NGOs (WWF, The Swedish Society for Nature Conservation (SSNC), public authorities and others). Though concerned about the environmental impact all stakeholders agreed that aquaculture has come to grow. The strategy is aimed to strengthen the development of a sustainable Swedish aquaculture sector including simplifying the administration and the environmental legislation of the aquaculture sector and fulfilling the Baltic Sea Action Plan (HELCOM, 2007). The work on a plan of action to implement the aquaculture strategy was initiated in December 2012.

The recent strategy for Swedish aquaculture (2012–2020) as well as the white paper: *Det växande vattenbrukslandet – Betänkande av vattenbruksutredningen* (SOU, 2009) envisaged a significant growth in Swedish aquaculture production towards 2020. The vision of a growing, sustainable and ethical Swedish aquaculture sector might be achieved by development of activities along the long Swedish coast line and in a share of the about 40,000 km² lakes (similar to the area of Denmark).

The strategy underlines the challenge of combining economical, ecological and social considerations through cooperation between the players of the aquaculture sector (farmers, feed producers etc.), researchers, professional organisations, NGOs, public authorities and decision makers/government.

The goal of the strategy includes:

- The production increases through improved competition; i.e. competency development (education and professional training) at all levels, product development, investments and specialisation
- Swedish aquaculture produces good and healthy food which is demanded by consumers in Sweden as well as in the rest of the world; i.e. breeding, quality products/diversification, certification, marketing and logistics
- Swedish aquaculture produces fish for restocking (tourism and conservation)

- Swedish aquaculture is characterised by a cooperation between the producers, producer organisations, researchers, NGOs and public authorities; i.e. "cooperation makes strong" coordinated by a National Aquaculture Council being established
- Reduced administrative/bureaucracy burdens and distinct regulations facilitate the development of the sector; i.e. uniform and simplified rules
- Swedish aquaculture is characterised by minor environmental impact; i.e. spatial planning, capacity of the ecosystem, removal of N and P, use of mussel meal, Swedish aquaculture will be at the forefront of environmental protection
- Swedish aquaculture contributes to an ecological, economic and social sustainable food production and resource efficient production. Swedish aquaculture contributes to secure food supply for the world. By-products from aquaculture are a valuable resource that will be utilized efficiently. The consumers are willing to pay premium prices for aquaculture products produced in an ecological and social sustainable way that support sustainable and competitive regional development
- New farming techniques are developed and farming of new species are tested through cooperation between the players of the aquaculture sector and the researchers; i.e. environmental efficient farming techniques
- Swedish aquaculture is characterised by health precautions and healthy animals
- Swedish aquaculture has access to genetic material of high quality
- Politicians at all levels and other related players perceive Swedish aquaculture as a safe, long termed and prosperous sector; sustainable aquaculture overall Sweden
- Municipal politicians and other local players focus on Swedish aquaculture; i.e. it is included in development strategies
- A majority of the Swedish municipalities identify and allocate relevant places for aquaculture in their master plans.

However, the fulfilment of the strategy will be operationalized through the recently initiated plan of action, which demands governmental commitment as well as financial support (EFF, state credit guarantees). This may also promote synergy in terms of new jobs, development of rural areas, infrastructure, internationalisation (research and education – EU-Nordic countries) etc.

To fulfil the Baltic Sea Action Plan (BSAP) to reduce the impact from nitrogen and phosphorus to the Baltic Sea (HELCOM, 2007), Sweden is committed to reduce the discharge of nitrogen by 29 % (20,780 ton/year) and of phosphorus by 34 % (290 ton/year) until 2021. The whole society and the industries (including aquaculture) have to contribute to the reductions in discharges.

Farming of mussels and sea weed might be one tool to remove nutrients from the sea. By farming e.g. blue mussels the nutrients are transformed into mussel meat which in turn can be used as seafood, or as mussel meal as an ingredient in feed for fish and land animals and the shells may be used as agricultural fertilizer. Compensation farming of mussels removing nutrient impact from fish farming or other emission sources may be a part of the solution (Lindahl & Kollberg, 2008). Thus, 1 tonne of mussels removes about 10 kg of nitrogen and 0.6 kg P (Petersen et al., 2012; Petersen, 2004). Related to aquaculture production the effect can be illustrated by production of rainbow trout. According to Dalsgaard & Pedersen, 2011 a production of 100 tonnes rainbow trout may discharge 4.7 tonnes N and 530 kg P. The 4.7 tonnes N may be removed by producing 470 tonnes mussels, which additionally may remove 282 kg P.

According to SOU, 2009 a significant potential for Swedish aquaculture production exists in the oligotrophic hydropower dams in northern Sweden. The report refers to estimates of SLU of a production potential of 50,000–70,000 tonnes fish/year from these water bodies. The actual production is, however, around 1,000 tonnes per year.

The hydropower regulation has given rise to conversion of huge water volumes into nutrient-poor (oligotrophic) lakes. According to Vrede et al., 2006, there may be three principal reasons for the water bodies being oligotrophic: (1) the dams obstruct the migration of salmonid fish from the sea to enter upper fresh water systems for spawning and to contribute to the nutrient input for the primary production, (2) the deep dams reduces the flows of nutrients, and (3) heavy erosion has destroyed the lakeshore zone due to a fluctuation of as much as 10–20 meters or more over the year in many regulated reservoirs. The level is generally highest in the autumn and then decreases to the minimum level in the winter, both because most water is released when the need for electrical energy is greatest, and because there is practically no inflow in winter.

In a recent report methods and guidelines for assessment of the environmental impact of fish farming in hydropower dams were outlined (Markensten et al., 2012). Different models for simulating nutrient load and effects, especially phosphorus, were compared. The reference condition (Tot-Pref) was defined as the condition level before establishment of aquaculture in the dam, which also was taken into account in the modeling. The report recommended utilization of a certain production potential in hydropower dams and preferable the most modified lakes. As a first assessment the report suggested a cut-off level of two times Tot-Pref as acceptable for "good ecological potential" in the lakes. However, a sampling program has to be implemented to monitor and control the environmental impact of an aquaculture activity on the ecological conditions in the lake. Based on the data the production potential may be adjusted.

Successful restoration experiments have been performed by adding nutrients to oligotrophic lakes (Vrede et al., 2006). Therefore, introduction of fish farming in these oligotrophic reservoirs might be an alternative way of adding nutrients to the ecosystem and contribute to restoring fish stocks and natural food webs. However, it has to be taken into consideration, that regulation and the loss of a normally functioning lakeshore zone still remains. Some of the nutrients from fish farming may be lost downstream and may have environmental impact there as well as in the final recipient – The Baltic Sea. However, research showed that properly controlled the nutrient loading and downstream environmental impact was assessed to be negligible (Vrede et al., 2006). Though cage farming of rainbow trout and to some extent also Arctic char in hydropower dams is increasing, market perspectives has to be considered as well to secure a market for the increased production.

9. Swedish aquaculture research

Swedish aquaculture research has been at the front edge since more than 40 years ago with Laxforskningsinstitutet in Älvkarleby and Alfa-Laval/EWOS's feed production facilities in Södertälje. Swedish research capacity has been internationally highly recognized and research groups have been attracted and involved in aquaculture related research through collaboration with aquaculture oriented research groups abroad, e.g. Norway, UK, Canada, Denmark, Finland, France etc.

Through a governmental initiative aquaculture research in Sweden was introduced at the Agricultural University of Sweden (SLU) in Umeå in 1987 (SOU, 2009). In Kälarne, the former Fiskeriverket has run a breeding programme for arctic char for about 25 years and the result has been a fast growing strain, Arctic Superior. Kälarna is now operated as cooperation between the Regional County of Jämtland, SLU and an association of the arctic char producers. Other breeding initiatives are going on with arctic char and rainbow trout in Jämtland and Västerbotten (SOU, 2009).

The aquaculture research at the University of Gothenburg (UGOT) covers the range from mainly strategic, basic marine research to specific applied goals, including mussel farming as a tool for removing nutrients from the marine environment and converting it into mussel meat or meal. External funding has been attracted from EU as well as Nordic research bodies, while relatively low funding so far has been obtained from the Swedish research council FORMAS. The research group includes 2–4 professors, 3–10 research scientists, and 4 Ph.D. students, cf. Annex 1.

However, FORMAS has recently funded a project in the area: *Microbes as a sustainable feed source to farmed fish*, as a strategic multi-disciplinary research project between UGOT and SLU.

UGOT was in charge of establishing Aquaculture Centre West (ACW) to gather the West coast aquaculture research and to further contribute to the national collaboration through matching the structure Aquaculture Centre North (ACN) established by the Agricultural University of Sweden (SLU). The cooperation is facilitated through the National Competence Centre for Aquaculture (NCCA) to connect education, research and improve competence skills in aquaculture, a kind of "Aquaculture Institute without walls".

ACW has recently launched its report no. 1, which deals with the biological premises for farming marine species along the Swedish west coast (Albertsson et al., 2012). The overall conclusion of the report was that the annual fluctuations in abiotic factors (salinity, temperature, oxygen) on the Swedish west coast do not practically allow traditional net- cage farming of the most relevant species (halibut, sole, turbot and Atlantic wolfish). A further challenge of open net-cages is the environmental impact. Hence, the report concluded that future aquaculture production on the Swedish west coast calls for new production technologies that can solve the identified challenges, i.e. possibility of adjusting/stabilizing abiotic factors as well as minimising the environmental impact. In practise this means multidisciplinary cooperation and research in new farming systems, i.e. using recirculation technolo-

gy and waste water treatment as well as integrated production systems. Finally the report called for needed infrastructure, i.e. marine hatchery for research and development (Albertsson et al., 2012).

The aquaculture research at SLU includes a range of areas within fish feed, environmental impact, welfare, breeding, e. g. alternative feed ingredients based on locally recaptured nutrients (nutrient loop concept), mussel meal, microbes as a protein source for aquaculture feed. Further, green growth is studied by using waste heat for farming warm water species and using organic side flows as protein sources. Alternative sources of marine lipids, i.e. GMO work with rapeseed to produce the essential Ω-3 fatty acids EPA and DHA and others is also on the agenda. Additionally, SLU took over research and data collection on fish from the former Fiskeriverket, cf. Annex 1. The research group on aquaculture at SLU includes 3 professors, 7 research scientists/Post Docs and 11 Ph.D. students.

Overall UGOT and SLU aquaculture research reflects a high activity in national and international collaborations, with high external funding and high publication rates in international high-rated journals. Integration of the research with the industry is developing.

At Chalmers University of Technology aquaculture competences are available in terms of expertise in modelling of Recirculation Aquaculture Systems (RAS) and waste water treatment, and hence Chalmers may contribute substantially to the development of new farming technologies and environmental efficient production strategies. The research group includes 1 research scientist and 1 Ph.D. student, cf. Annex 1.

Sustainable aquaculture depends on an adequate balance between environmental and economic performance within ecological constraints, which by the end of the day includes aspects of climate change mitigation and adaption. These issues are in focus in the research field Industrial Ecology at the Royal Institute of Technology (KTH) – cf. Annex 1.

The research uses a philosophic and logistic approach of sustainable development of fish supply and fish stock management, including main challenges for improved local fish supply close to the consumers through improved networking between stakeholders, adequate farming technologies, and dissemination and education of skilled professionals. KTH only has a couple of researchers dealing with aquaculture. KTH has established a cooperation with SLU on rearing technology utilizing the joint competence between their technical (KTH) and biological (SLU) competences.

The cooperation at KTH is further extended to Chalmers, regional authorities as well as private companies and consumers.

Environmental impacts associated with aquaculture and inter-linkages between aquaculture and fisheries are among key research areas at the Beijer Institute of Ecology Economics at Stockholm Resilience Centre. The research focuses on resources and how aquaculture can increase the socio-ecological resilience. Therefore, the research group does not include core aquaculture research, but its interactions with the ecosystem. At Beijer 1 research scientist (docent), 1 post-doc and 1 Ph.D. student are working with aquaculture aspects, cf. Annex 1.

The dominating aspect of the research is the ecosystem management approach with a socio-economic dimension. Among others the research questions are: Can aquaculture enhance the resilience of global food supply, i.e. trade-offs between agricultural food production and aquaculture – and the environmental footprint? The holistic ecosystem approach also includes the protection of the biodiversity as well as social ecological aspects.

The Section of Fish and Shellfish (SFS) at the National Veterinary Institute, SVA, is the National reference laboratory for all serious diseases in fish and shellfish. The most important role of SVA/SFS is to focus on contagious and other serious infectious diseases that imply a threat to animal health, supplies of animal foodstuffs as

well as food safety. Diagnostic capacity for the most feared contagious animal diseases is available at SVA, cf. Annex 1. The resources for aquaculture research in SFS include 3 part-time research scientists and a Ph.D. student.

As a national reference laboratory SFS is a main player in the National Health Control. However, the owner of the National Health Control Program is the Board of Agriculture (BA), but since about 20 years ago the responsibility for the practical running of the program has been delegated to the Fish Health (FH) AB, which is the industry's own health organization. However, the inappropriateness of the industry doing the sampling has been realised and hence SVA may take over the role of organizing the sampling. Further, SLU and SVA are collaborating with the private health service and the Agricultural Board to evaluate the possibility to create a *Fish Health Centre* at Ultuna, Uppsala, as both the SLU and SVA activities of fish health already are located there, including extension of the education efforts within fish health and control.

The research and diagnostic competences at SVA/SFS are at high international level including specific knowledge in advanced molecular techniques for diagnostics and characterization of pathogens. The expertise is crucial to sustain the unique high health status of Sweden, in particular for developing Swedish aquaculture to bigger volumes and greater diversification of farmed species due to the greater risks of disease outbreak and spreading of diseases. Hence, under these conditions it is important for SVA/SFS to extend the international cooperation, including the Nordic countries, to secure up-to-date veterinary information, diagnostic techniques as well as prophylactic measures.

To summarize Swedish aquaculture research institutions have about 5–7 professors, 16–23 research scientists and about 18 Ph.D. students. This is of course an approximation that varies over time.

Regarding publication of Swedish aquaculture research activities during 2007–2012 a search at *Web of knowledge* using the key words: "aquaculture" or "fish farming" showed 14,528 records. Of these 209 had a Swedish author and the distribution was:

Stockholm University	73
University of Gothenburg	37
Royal Swedish Academy of Science	22
Swedish University of Agricultural Sciences	22
Uppsala University	21

10. Other stakeholders

The development of aquaculture has to consider the whole range of views among stakeholders and this also includes the perceptions of the aquaculture organisations, environmental authorities and the NGOs as well as the general public's perception of aquaculture. Finally the political framework and concrete governmental actions and back up on aquaculture are fundamental for the development of Swedish aquaculture in practise.

The Ministry of Rural Affairs has expressed a positive will from the government to support aquaculture production. Thus action has been taken to simplify legislations related to aquaculture, including adjustment of monitoring fees to a more comparative level to similar food production (agriculture). Further the ministry had expressed initiative to fulfil their obligation in the strategy (Jordbruksverket, 2012c) to establish a National Aquaculture Council through the Board of Agriculture, cf. Annex 1.

The Swedish Aquaculture Organisation (SAO) – Vattenbrukarnas Riksförbund (VRF) is a national aquaculture organisation which acts as a spokesman to support the interests of the Swedish aquaculture farmers to the authorities and the society and promotes the development of aquaculture in Sweden. The members (60–70) include producers of fish and shellfish for human consumption, restocking and recreational fishery.

The organisation has no secretariat – only a board. This means that the organization can give no support/consultancy for the farmers. However, to fulfil the obligations in the strategy a stronger SAO and a secretariat is needed and hence financial support, e.g. through EMFF.

The Shellfish Producers Organisation (SPO) was established in 2007. The organisation counts 12 members on the west coast. However, one of the 12 members is the main producer and KRAV certified; while the remaining 11 members are small producers, cf. Annex 1. The majority of the Swedish shellfish production is sold in the Swedish market, and marketing remains a challenge for extending the production.

The Board of Agriculture (BA) – Jordbruksverket – took over aquaculture issues from the former Fiskeriverket and shall according to the Board's instructions contribute to the promotion and development of aquaculture in Sweden. Thus, BA is the Government's expert authority in matters of agri-food policy, and is responsible for the agricultural and horticultural sectors, which also includes fisheries and aquaculture, i.e. separate division of aquaculture. The head office of BA is in Jönköping. However, regional offices and working places are placed in southern and central Sweden dealing with environmental issues, water, seeds, inspection, and livestock registers, while others are working at District Veterinary stations all over Sweden.

BA is dominated by the agricultural sector and requested expertise in aquaculture is currently based on knowledge and experience from agriculture, though basic differences in farming terrestrial and aquatic animals.

The Board of Agriculture has got a significant role in the management of aquaculture activities and is expected to be "the one door" to facilitate the administra-

tive procedures for the farmers to deal with in relation to permissions, supervisions/inspections etc.

BA is improving knowledge and dissemination about aquaculture to the public, cf. website: *www.jordbruksverket.se*. Further, BA handles the European Fisheries Fund (EFF), i.e. evaluation of applications.

The Swedish Agency for Marine and Water Management (SwAM) is a governmental authority monitoring Swedish water bodies (seas, lakes and streams). SwAM is preparing guidelines for the County administrative boards and the municipalities, i.e. making guidelines for officers giving permissions/inspecting aquaculture farms. Further SwAM is responsible for the fishery legislation (restocking) and Swedens implementation of the Common Fisheries Policy (CFP).

SwAM has taken over fish and fishery related tasks from the former *Fiskeriverket* and general freshwater and coastal zone management from the Swedish Environmental Protection Agency. However, grey zones still exist on responsibilities and tasks between BA and SwAM.

WWF – Sweden supports international operations of WWF as well as Swedish research, education and practical nature conservation work, i.e. related to forests, climate, Baltic Sea and Marine areas, cultural landscapes and education and training. WWF has the ambition to contribute to make Sweden become a world leader of climate-smart energy solutions, cf. Annex 1.

WWF believes in an aquaculture business producing sustainably while securing biodiversity and ecosystem based management, i.e. sustainable feed sourcing, low carbon footprint/LCA, low freshwater and minimal land use as well as low negative environmental impact, e.g. using recirculation technology. However, market analyses on the demands of the consumers including niche species as well as risk analysis regarding sustainable regional development, international competition and adaption to climate change should also be considered.

Aquaculture obviously needs an improved image and credibility among the public, including government awareness and consumer acceptance. WWF is contributing to promoting green growth of aquaculture through the Global Aquaculture Dialogues, where WWF has been putting great efforts in working with all the stakeholders including producers, retailers and NGO's to develop a set of transparent standards that reflect world's best practice in environmental management of fish and shellfish farming. Recently the standards on FW trout farming were finished and these standards now represent a comprehensive collection of global best environmental management practice. All involved stakeholders believe that adoption of an independent labelling and certification scheme, e.g. Aquaculture Stewardship Council (ASC), will provide more credibility and allow for reductions in the "Food guide" red tape as the standard will ensure best practice management.

Swedish aquaculture research funding bodies

FORMAS (the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning) is a governmental research funding body. One key research area for FORMAS is agricultural sciences, animals and food. This includes fishery and aquaculture. A search on "Vattenbruk" (aquaculture) in FORMAS' project database shows that there are around 25 research projects funded by FORMAS that in whole or part are dealing with aquaculture.

Vinnova (the Swedish Governmental Agency for Innovation Systems) promotes collaboration between companies, universities, research institutes and the public sector with the aim to strengthen Sweden's innovativeness. One way Vinnova does this is by funding research and innovation. Within the interdisciplinary research program for food *Tvärlivs* (also including FORMAS and the food industry) there is currently one project funded with relevance for aquaculture.

BONUS is a joint Baltic Sea research programme producing knowledge to support development and implementation of regulations, policies and management practices specifically tailored for the Baltic Sea region. It issues calls for competitive proposals and funds projects of high excellence and relevance based on its Strategic Research Agenda (BONUS, 2011). BONUS is supported by national research funding institutions in the eight EU member states around the Baltic Sea (from Sweden – among others – MISTRA, FORMAS and Vinnova) and by the European Union. BONUS announced two calls at the end of 2012, one on viable ecosystem and one on innovation. Up to a total of EUR 38 million is made available through these two calls. Proposals will be evaluated during 2013. Earliest start of projects will be at the end of 2013.

Sustainable aquaculture in the Baltic Sea will probably be specifically addressed in a second BONUS innovation call at the end of 2013.

Both the EU research framework programme (**FP7** as well as the new framework programme **Horizon 2020**) and the **European Maritime and Fisheries Fund** (EMFF) provide funding that might be of relevance for aquaculture. Developing competitive European aquaculture is one specific activity mentioned in the proposed specific programme for the implementation of Horizon 2020 (EU, 2011).

11. Why develop Swedish aquaculture?

Sweden has a long tradition for aquaculture as the basic conditions are available, i.e. large water resources of good quality (both marine and fresh water), high veterinary status, generally well developed public infrastructure and adequate climate conditions for farming salmonids. However, farming of warm water species using waste heat from power plants or other industries might also be relevant (using nutrient side-streams). Swedish aquaculture has the potential to develop into a green growth well performing business producing environmentally sustainable healthy food with low ecosystem and climate impact. The sector may be a driving force in the development of employment, infrastructures and improvement of economic and social conditions in rural areas.

Thus, Swedish aquaculture has the potential to contribute significantly to food security and the global production of fish based animal protein in a sustainable way. This also includes processing of aquaculture products into value added products further improving employment and profit. This innovative development requires research on feed sourcing and recirculation production systems with minimal environmental impact. It is furthermore important that aquaculture becomes an integrated part of the food production system, i.e. being accepted as an equal food producing sector in line with the agricultural sector.

High level research in aquaculture issues is going on at Swedish research institutes, but more benefits might be achieved through development of more cooperation with relevant Nordic/European research institutes, including use of available infrastructures.

A basic condition for successful development of Swedish aquaculture is improvement of the cooperation between the main stakeholders involved in aquaculture in Sweden. This may be achieved through strong integration of the political frameworks, regional administrations, the entrepreneurs of aquaculture production and the national research groups on aquaculture.

These connections may be facilitated through the national Aquaculture Centres (West, North and East) interconnected through the National Competence Centre for Aquaculture.

Further, as a part of the strategy for Swedish aquaculture the National Aquaculture Council being formed may support the linkage between the stakeholders in the aquaculture sector. Stronger integration of the stakeholders within the aquaculture sector is assessed an important platform for multidisciplinary Research and Development programs for strategic and efficient development of Swedish Aquaculture.

12. Analyses and conclusions

Swedish aquaculture research is overall assessed to be of very high quality and highly acknowledged at international level.

The establishment of the regional aquaculture centres and the National Competence Centre for Aquaculture could make a common and focused platform for cooperation on research and education, exchange and transfer of knowledge from research to aquaculture practice. These structures may also facilitate improved common understandings and extend a closer cooperation between the researchers and the farming sector so as to achieve main farming challenges reflected in the research strategies and activities. Further, integration of biological and technical research combined with education and training of skilled professionals as well as authority staff is called upon.

Hence, there is also a need for an adequate coordination of the administration of the sector, including the environmental legislation and spatial planning, i.e. pointing out adequate sites for aquaculture production. The Swedish environmental legislation is very strict and complicated making challenges to get permissions to and running aquaculture production. Further, the development is hampered by many authorities being involved in the permission and inspection processes. This appropriateness is being taking care of through the Board of Agriculture, which is supposed to be "the facilitating one door" for the farmers to deal with in relation to permissions and inspections. The outcome remains, however, to be seen.

Aquaculture contributes to the global food security and due to this fact aquaculture has to be an integrated part of the Swedish food production in line with agriculture. From a food supply as well as an ecosystem point of view it is important to validate the net production costs and environmental impact from a certain production of aquaculture products contra a similar production of agriculture products, i.e. a LCA comparing the relative carbon foot- print, cf. fig. 5.1. The outstanding feed efficiency of aquaculture production was shown in a study of Torrissen et al., 2011 as the carbon footprint from aquaculture production was significantly lower than e.g. from beef production. Hence, Sweden has the potential to increase their share of the aquatic food supply in a sustainable way as well as creating new jobs.

Although large water areas, e. g. hydropower dams, are available for aquaculture production in Sweden which may tolerate nutrient load, the strategy for further development of Swedish aquaculture has to include waste water treatment, i.e. using recirculation technology to minimize the environmental impact, in particular to the Baltic Sea. Further utilisation of waste heat may improve the profitability of the production and further diversify the production in farming warm water niche species. Aquaculture may develop to be an environmental service as well.

Recirculation aquaculture systems may even disconnect the aquaculture production from the external environment, i.e. no environmental impact by developing innovative solutions to waste water treatment through the mechanical and biological processes of the system. Research groups at Chalmers, KTH, SLU, UGOT, Stockholm Resilience Centre and maybe others may do common progressive efforts in cooperation with Nordic/European partners with expertise in the field, including cooperation on existing or new infrastructures. However, in a green growth

perspective the wastes of carbon, nitrogen and phosphorus from aquaculture production should be looked upon as resources to be integrated and utilized in other production systems. In particular phosphorus is a limited and non- renewable resource. Hence there is an urgent need to develop technologies to recover and recycle phosphorus waste from aquaculture production.

Novel productions of feed may include ingredients like micro- and macro-algae, bacteria, fungi (e.g. utilizing organic side-streams from paper mills to produce protein sources) and processing waste. Further, the research may be extended to integrated systems, e.g. integrated production of fish, shellfish/mussels and horticultural plants.

A growing aquaculture industry in Sweden including diversification of the production of fish and shellfish, organic production or other certification schemes, also implies developed market channels to sell the products. To get the consumer acceptance of eating fish and shellfish/mussels requires focused dissemination of sustainable production, i.e. minimum environmental impact, reuse of nutrients and waste heat (Green energy), labelling etc. Further, the Swedish food processing industry could benefit from developing new products from aquaculture including ready-made food.

The governmental policy on aquaculture should reflect the conclusions of the official report *Det växande vattenbruket* (SOU, 2009) and the strategy *Svenskt vattenbruk – en grön näring på blå åkrar, Strategi 2012–2020* (Jordbruksverket, 2012c).

For a significant and powerful Swedish aquaculture to develop, strong and committing policy instruments should be coordinated and managed. This means that the strategy for aquaculture needs to be followed by a long term focused research policy on aquaculture and responsibility for putting it into force as well as availability of adequate funding from national and international sources (e.g. EMFF, research councils, EU, Nordic and BONUS). Finally, the financial sector should be made more confident with aquaculture to facilitate investments in aquaculture.

Aiming to enable a progressive change of the Swedish aquaculture sector the Working Group recommends that MISTRA establishes a research program on aquaculture including:

- Global ecosystem aspects of aquaculture production including diversification, production systems, species, products, etc.
- Environmental efficient production with trapping of solid waste and balanced nutrient management (recirculation technology, waste heat/green energy/integrated production systems)
- Policy instruments: legislation, economic incentives, socioeconomic dimensions, labelling, organic farming and other certification schemes.

These issues were discussed at a hearing with the stakeholders, cf. Annex 2. The overall conclusion from the hearing was that the proposed themes were assessed relevant to be addressed for development of Swedish aquaculture.

13. Scope of a new research initiative on Aquaculture

The term aquaculture corresponds to the Swedish term Vattenbruk. Aquaculture is the cultivation of fish, shellfish or plants in fresh water (FW) or sea water (SW). Aquaculture has become the fastest growing food producing sector in the world. According to FAO the production was 60 million tonnes of fish and crustaceans and 20 million tonnes of aquatic plants in 2010, which were similar to the amount of wild caught fish. Hence, aquaculture contributes significantly to the global food security. Further, aquaculture is a climate friendly way of food production as it is much more feed efficient in producing food compared to land living warm-blooded animals, i.e. lower emissions of greenhouse gasses (carbon footprint).

At European level aquaculture production contributes with 10 % of the consumption, while 65 % of the European consumption of aquaculture products are imported (EU, 2012b). Although Sweden has great potentials for aquaculture production only about 12,000 tonnes were produced in 2011, while 72,000 tonnes of mainly salmon were imported from Norway (Norges Sjømatsråd, 2013).

The Swedish aquaculture industry may develop into a green well performing business producing environmentally sustainable healthy food with low climate impact. This could make Sweden more self-sufficient with aquaculture products and contribute to transfer of green technologies. Further the processing industry may increase, which altogether could contribute to employment, infrastructures and improvement of economic and social conditions in rural areas.

Sustainable aquaculture development should have a holistic approach considering the integration of environmental, economic and social sustainability. Research should be trans-disciplinary including scientific knowledge as well as know-how from practice and policy-making. Further the research should be integrated with resilience science and take a food systems approach considering relevant aspects of the food chain between farm and fork, e.g. producers, feed industry (sourcing of ingredients), food industry, retail and consumers.

MISTRA is looking for innovative solutions for a long term perspective of sustainable and profitable aquaculture development. Therefore, the research programme should catalyse significant changes and substantially contribute to make a difference to the development of Swedish aquaculture as an integrated part of the food production system.

The following three research themes have been identified as the most relevant research areas to support the development of Swedish aquaculture sector:

- Global ecosystem aspects of aquaculture production including diversification, production systems, species, products, etc.
- Environmental efficient production with trapping of solid waste and balanced nutrient management (recirculation technology, waste heat/green energy/integrated production systems)
- Policy instruments: legislation, economic incentives, socioeconomic dimensions, labelling, organic farming and other certification schemes.

Potential research topics and examples of research questions are briefly described below. Cooperation between different scientific disciplines and education related to aquaculture, stakeholder's organisations and entrepreneurs in the aquaculture businesses, policy makers and authorities is strongly encouraged. Swedish competitiveness on aquaculture production should be considered both with regard to sustainably market driven development and knowledge support for policy making and consumer incentives. Swedish competitiveness should be increased through the development of new aquaculture strategies including a global ecosystem perspective. Research should also include international cooperation to provide leadership in an international context.

Environmental efficient aquaculture production should be developed, e.g. using recirculation technology or other innovative concepts to achieve minimum environmental impact by disconnecting the aquaculture production from the external environment. In a green growth perspective the wastes from aquaculture production should be looked upon as resources to be integrated and utilized in other production systems. In particular phosphorus is a limited and non-renewable resource. Hence there is an urgent need to develop technologies to recover and recycle phosphorus waste from aquaculture production.

Novel feeds and feeding technologies including nutrient efficient feed ingredients should be addressed i.e. recapture of nutrients, micro- and macro-algae, bacteria, fungi, processing waste, side-streams, other single cell organisms, invertebrates, etc.

The development of Swedish aquaculture must be within the resilience of the ecosystem including ecological and socio-economic aspects, and contribute to future food security. A specific aspect might be incorporation of nutrients in pelagic food webs as contribution to the restoration of oligotrophic water systems, i.e. hydropower dams. Hence, aquaculture may be developed into an environmental service.

Diversification in new value-added niche production and products, including breeding, organic production or other certification schemes, should be considered. However, priority should be given to native Swedish species of fish and shellfish.

It is important to integrate biological and technical aquaculture research with education and training of skilled professionals in the business as well as authority staff working with aquaculture.

Dissemination about sustainable Swedish aquaculture to get consumer awareness and acceptance of eating Swedish aquaculture quality products should be addressed.

Research on policy instruments should include development of sustainable and profitable Swedish aquaculture including legislation, economic incentives, socio-economic dimensions, organic farming and other certification schemes.

14. Funding and commitments from other stakeholders

An investment on aquaculture research by MISTRA should be linked to commitments between governmental, regional authorities and the farming industry.

Engagement from MISTRA calls for the following commitments as expressed in the strategy: *Svenskt vattenbruk – en grön näring på blå åkrar. Strategi 2012–2020*.

Ministry of Rural Affairs, national authorities, county administrations, municipalities:

- Simplify legislations related to aquaculture
- Lower administrative costs/monitoring fees of aquaculture
- Active role of the National Council of Aquaculture
- Promote national breeding programs
- Monitor the health status of aquaculture animals in Sweden as well as international
- Promote sustainable sourcing of feed ingredients (re-using, side-streams etc.) at national as well as EU level
- High priority of aquaculture initiatives in the new EMFF program (2013 →)
- Allocation of certain amounts of annual budgets for research council budgets to funding for aquaculture projects
- Improved education and training of staff in fish administrations (Board of Agriculture, county administrations etc.), environmental and fish health inspections, fish farm staff etc.).
- Take responsibility of all issues related to permissions, supervisions and inspections of aquaculture productions ("One door in")
- Facilitate establishment of new productions and extension of existing
- Efficient review/case handling (max. duration)
- Spatial planning and siting of aquaculture enterprises in cooperation with the industry
- Dissemination of information about aquaculture and potentials
- Cooperate with the industry on possibilities and limitations on aquaculture activities.

Farming industry:

- Keep attention to market requests on aquaculture products
- Diversification of production (species, quality products, certification and labelling, organic production schemes etc.)
- Use best available technologies (environmental efficient production, use by-products and side-streams)
- Trained and skilled personal to secure fish health, prevent disease transmission and environmental impact
- Cooperate to sustain the high veterinary status of Swedish aquaculture
- Proper distribution systems for aquaculture products
- Support network and advisory between the industry and relevant authorities
- Specify the need of education and development of competence
- Engagement in research and development of technology within aquaculture
- Responsible and competent production of valuable and healthy products
- Demonstrate a positive image of aquaculture and its significance for development of the society
- Encourage investments in aquaculture.

Besides a common understanding and a supportive attitude a MISTRA financial commitment should be matched by financing or other commitments from main stakeholders. Additional financing is expected from the Government through the research councils or governmental agencies in charge of aquaculture issues. A commitment from the industry, including farmers associations and regional and local organisations supporting aquaculture business, could be active participation in research activities and/or, where appropriate, to make facilities (owned and/or operated by the industry) available for scientific purposes. MISTRA should also expect, as a general rule, matching funds from participating universities and research institutes to show their commitment.

15. References

Albertsson, E., Strand, Å., Lindegarth, S., Sundell, K.S., Eriksson, S. and Björnsson, B.T. (2012): *Marin fiskodling på den svenske västkusten: Biologiska förutsätninger*, Rapport no. 1 from Vattenbrukscentrum Väst, Göteborgs Universitet (Report in Swedish).

BONUS (2011): *BONUS Strategic Research Agenda 2011–2017*, The joint Baltic Sea research and development programme, BONUS Publication No. 12.

Dalsgaard, A.J.T., Pedersen, P.B. (2011): *Solid and suspended/dissolved waste (N, P, O) from rainbow trout (*Oncorhynchus mykiss*)*, Aquaculture, Vol. 313, No. 1–4, p. 92–99.

EU (2011): *Proposal for a Council Decision establishing the Specific Programme Implementing Horizon 2020 – The Framework Programme for Research and Innovation (2014–2020)*, European Commission, COM (2011) 811 final, page 57.

EU (2012a): *EU Commission (2012) Blue Growth – opportunities for marine and maritime sustainable growth*, (COM (2012), 494 final.

EU (2012b): *Common objectives and targets for the strategic guidelines on sustainable aquaculture that the Commission plans to adopt in February 2013* (Confidential working paper).

FAO (2012a): *www.fao.org/fishery/aquaculture/en*

FAO (2012b): *www.fao.org/fishery/statistics/en*

FAO (2012c): *FAO Statistical Yearbook 2012*, *www.fao.org/docrep/015/i2490e/i2490e00.htm*

HELCOM (2007): *www.helcom.fi/BSAP/MinisterialMeeting/en_GB/Ministerial_Meeting_2007/*

Jordbruksverket (2012a): *www.jordbruksverket.se*

Jordbruksverket (2012b): *Vattenbruk 2011. Aquaculture in Sweden 2011.*, Statistiska Centralbyrån, Sveriges Officiella Statistik – Statistiska Meddelanden (JO 60 SM 1201).

Jordbruksverket (2012c): *Svenskt vattenbruk – en grön näring på blå åkrar*, Strategi 2012–2020.

Kiessling, A.: (2013): *Vattenbruk i Sverige – då och nu* In Sjömatboken, FORMAS, 5 pp.

Lindahl, & Kollberg, S. (2008): *How mussels can improve coastal water quality*, *www.bioscience-explained.org/* vol 5, no. 1.

Markensten, H., Fölster, J., Vrede, T. and Djodjic, F (2012): *Näringspåverkan av fiskodling i regleringsmagasin*, Institutionen för vatten och miljö, SLU. Rapport 2012: 20.

NORD-OSTRON (2013a): *Strategic Approaches for Aquaculture Industry Development: Flat Oyster Cultivation in Scandinavia*, Prepared by Joyce, A., Lindegarth, S., University of Gothenburg; Petersen, J.K. Danish Shellfish Centre and Murphy, C., Norwegian University of Life Sciences. Interreg IV project NORD- OSTRON.

NORD-OSTRON (2013b): *Handbok för ostronodlare – et resultat af Projekt Nord-Ostron 2009–2012*, Available in Swedish, Norwegian and Danish, Susanne Lindegarth, University of Gothenburg (susanne.lindegarth@bioenv.gu.se).

Norges Sjømatråd (2013): *www.seafood.no*

Paavola, I.-L., Ekroos, A., Veinla, H. and Reelve, K. (2012): *Environmental regulation of aquaculture in the Baltic Sea region*, *http://www.aquabestproject.eu/media/8660/aquabest_3_2012_environmental_regulation_of_aquaculture.pdf*

Petersen, J.K., Timmermann, K., Carlsson, M., Holmer, M., Maar, M. and Lindahl, O. (2012): *Mussel farming can be used as a mitigation tool – A reply*, Marine Pollution Bulletin, 64,2 Pp. 452–454.

Petersen, J.K. (2004): *Bæredygtig udnyttelse af muslinger i danske farvande* [*Sustainable use of mussels in Danish Waters*], Report to Muslingeudvalget, Danish Ministry of Food, Agriculture and Fisheries.

SOU (2009): *Det växande vattenbrukslandet – Betänkande av vattenbruksutredningen*, Statens Offentliga Utredningar – SOU 2009: 26.

Torrissen, O., Olsen, R.E., Toresen, R., Hemre, G.I., Tacon, A.G.J., Asche F., Hardy, R.W. and Santosh, L. (2011): *Atlantic salmon* (Salmo Salar*): The "Super-chicken" of the Sea?*

Vattenbruk 2011 – Aquaculture in Sweden 2011, Sveriges Officiella Statistik – Statistiska Meddelanden JO 60 SM 1201. Jordbruksverket & SCB.

Vrede, T., Rydin E. and Milbrink, G. (2006): *Restoration of fish stocks in oligotrophicated regulated reservoirs*, In *Dams under Debate* from FORMAS, the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning pp. 85–92.

Åsgård, T., Austreng, A., Holmefjord, I., Hellestad, M. & Shearer, K.D., 1999: *Resource efficiency in the production of various species*, In: Svennevig, Reinertsen, *New sustainable aquaculture*, Food for the future, Balkerma, Rotterdam. Pp. 171–183.

Åsgård, T. & Austreng, A., 1999: *Optimal utilization of marine proteins and lipids for human interest*, In: Reinertsen & Haaland, *Sustainable fish farming*, Balkema, Rotterdam. Pp. 79–87.

16. List of abbreviations

ACE Aquaculture Centre East

ACN Aquaculture Centre North

ACW Aquaculture Centre West

AQUABEST An inter-regional project partly financed by EU on potentials of aquaculture to become a nutrient neutral food production system in the Baltic Sea Region.

AQUACULTURE The cultivation of fish, shellfish or plants in fresh water (FW) or sea water (SW) – In Swedish: *Vattenbruk*.

ASC Aquaculture Stewardship Council. An independent non-profit organisation, managing the global standards for responsible aquaculture, which are developed by the Aquaculture Dialogues and coordinated by WWF.

BA The Board of Agriculture – Jordbruksverket

BONUS Baltic Organisations' Network for Funding Science. A joint Baltic Sea research programme to facilitate development and implementation of regulations, policies and management practices specifically tailored for the Baltic Sea Region (BSR).

BSAP Baltic Sea Action Plan. A plan to restore the good ecological status of the Baltic Sea, adopted by HELCOM in 2007. The plan includes targets to reduce discharges of Nitrogen (N) and Phosphorus (P) to the Baltic Sea. BSR: Baltic Sea Region

CFP Common Fisheries Policy

DHA Docosahexaenoic acid. An essential and healthy poly-unsaturated Ω-3 fatty acid, which cannot be made by the human body. Primary structural component of the human brain. Originates from marine algae and passed through the food web to fish/fish oil and consumed by humans.

EFF European Fisheries Fund

EMFF European Maritime and Fisheries Fund

EPA Eicosapentaenoic acid. An essential and healthy poly-unsaturated Ω-3 fatty acid, which cannot be made by the human body. Originates from marine algae and passed through the food web to fish/fish oil and consumed by humans.

FAO Food and Agriculture Organization of the United Nations

Food Guide A guide developed by WWF, together with the Seafood Choices Alliance (*www.seafoodchoices.com/*), North Sea Foundation (*www.noordzee.nl/*) and the Marine Conservation Society (*www.mcsuk.org/*). Based on a certain methodology, the guide indicates the sustainability of seafood species, i.e. giving "red tape" to species recommended to refrain from eating, "green tape" to species assessed sustainable to be consumed and "yellow tape" to species that are assessed still not fully sustainable for consumption.

FORMAS The Swedish Research Council for Environment (and Nature), Agricultural Sciences (Animals and Food) and Spatial Planning.

FW Freshwater

GMO Gene Modified Organisms, i.e. its genetic material has been altered/manipulated using genetic engineering/biotechnology.

HELCOM HELsinki COMmission. Baltic Marine Environment Protection Commission, i.e. intergovernmental organisation of the nine Baltic coastal countries and the EU, protecting the marine environment from all sources of pollution.

KTH Royal Institute of Technology – Kungliga Tekniska Högskolan

LCA Life Cycle Analysis. Environmental impact assessment associated with all the stages of a product's life from-cradle-to-grave.

NAC National Aquaculture Council

NACC National Aquaculture Competence Centre

NGO: Non-Governmental Organization

Oligotrophic Nutrient-poor (lake) e.g. Hydro-power dams

RAS Recirculation Aquaculture Systems

SAO The Swedish Aquaculture Organisation – Vattenbrukarnas Riksförbund (VRF)

SFS The Section of Fish and Shellfish at SVA

SLU The Agricultural University of Sweden – Sveriges Lantbruks Universitet

SME Small and medium-sized enterprise

SOU Statens Offentliga Utredningar

SPO The Shellfish Producers Organisation – Svensk Skaldjursodlings Producentorganisation

SSNC Swedish Society for Nature Conservation

SVA The Veterinary Institute – Statens Veterinärmedicinska Anstalt

SW Sea water

SwAM The Swedish Agency for Marine and Water Management – Havs- och Vattenmyndigheten (HaV)

UGOT University of Gothenburg

VINNOVA Swedish Governmental Agency for Innovation Systems

WG Working Group

WWF World Wild Fund for Nature

Annex 1. Meetings with stakeholders

An important element of the evaluation of Swedish aquaculture research was meetings and communication with a broad range of stakeholders within Swedish aquaculture.

Meetings were held with the following stakeholders:

Gothenburg, 1st – 2nd October 2012

Organisation	Contact	Contact details
The Swedish Aquaculture Organisation – SAO Vattenbrukarnas Riksförbund (VRF)	Henrik Hammar	henrik.hammar@moderat.se
The Shellfish Producers Organisation – Svensk Skaldjursodlings Producentorganisation	Björn Lindblad	bjorn@lindbladkonsult.se
The Swedish Agency for Marine and Water Management (SwAM) – Havs- och Vattenmyndigheten (HaV)	Josefin Walldén	josefin.wallden@havochvatten.se;
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	Erland Lettevall	erland.lettevall@havochvatten.se
	Sofia Brockmark	sofia.brockmark@havochvatten.se
The Board of Agriculture – Jordbruksverket	Ulrika Bergman	Ulrika.bergman@jordbruksverket.se
University of Gothenburg	Björn Thrandur Björnsson	thrandur.bjornsson@bioenv.gu.se;
	Kristina Sundell Snuttan	kristina.sundell@bioenv.gu.se
Chalmers	Torsten Wik	torsten.wik@chalmers.se

Stockholm, 3rd -5th October 2012

Organisation	Contact	Contact details
Ministry of Rural Affairs – Landsbygdministeriet	Magnus Kindbom	magnus.kindbom@rural.ministry.se birgitta.rosenlof@rural.ministry.se
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	Johan Andersson Arnell	
World Wild Fund for Nature (WWF) – Sweden	Inger Näslund	inger.naslund@wwf.se
	Charlotta Järnmark	Charlotta.Järnmark@wwf.se
The Agricultural University of Sweden – Sveriges Lantbruks Universitet (SLU)	Anders Kiessling	Anders.Kiessling@slu.se
Royal Institute of Technology – Kungliga Tekniska Högskolan (KTH)	Björn Frostell	frostell@kth.se
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	Anders Hellström	anders.hellstrom@sva.se

University of Gothenburg (UGOT)

Participants

Prof. *Björn Thrandur Björnsson* (BTB)
Prof. *Kristina Snuttan Sundell* (KSS)
Thomas Nilsson (TN), MISTRA
Alfred Jokumsen (AJ), MISTRA WGA

The Fish Endocrinology Laboratory (FEL), **Department of Biological and Environmental Sciences, Faculty of Science, University of Gothenburg** (UGOT) has been building up an active research group since 1989 and the group currently consists of 2 professors, 3 research scientists, 2 postdocs and 3 PhD-students.

Björn Thrandur Björnsson (BTH) is mainly interested in mechanisms of endocrine regulation, i.e. how endocrine systems control physiological functions in fish, combining fundamental research with applied studies related to aquaculture. Currently the main focus is on the multiple roles of the GH – IGF-I system in teleost's, including those in larval development, growth, osmoregulation, smoltification, and sexual maturation, as well as the influence of GH – IGF-I on behaviour and the ecological consequences of growth.

The research topic includes:

- Hormones, binding-proteins and receptors
- GH, IGF-I, leptin, ghrelin, CCK, GRP, cortisol
- Larval development, metamorphosis, smoltification, growth, metabolism, puberty and sexual maturation

Kristina Snuttan Sundell (KSS) is mainly interested in intestinal physiology; immunology and barrier function from a basic perspective and in relation to environmental stressors, i.e. endocrine control of gastrointestinal function during nutrient uptake, osmo- and ion-regulation and the role of the gut as a primary barrier against a hostile environment. Special emphasis is placed on translocation of pathogens, alternative food sources, stressful husbandry conditions as well as developmental processes during the lifecycle and the role of cortisol in stress and development.

The research topic includes:

- Primary barrier functions, intestinal permeability, mucus protection, tight junction proteins and membrane structure
- Intestinal transport functions, ion and water transport, nutrient uptake and pathogen translocation
- Intestinal immunology, innate immune responses, inflammatory responses
- Fish health and welfare, stress coping strategies and personalities

Recently (since 2011) FEL has initiated and leads the Aquaculture Centre West (ACW). The aim of ACW is to:

- Visualize research activities through a web site
- Arrange and participate in multiple outreach activities, targeting authorities, industry and the public
- Coordinate and scientifically support innovative projects within aquaculture
- Create meeting places and communicate research to stakeholders

- Coordinate education and competence development within the aquaculture sector

www.vbcv.science.gu.se/
www.nkfv.se/

The projects initiated within the FEL group range from purely fundamental research (physiological and endocrine mechanisms) to projects with specific applied goals. Much of the recent research can, however, be labelled as strategic, basic research, i.e. where fundamental physiology is studied in areas (species, functions) where applied (production) problems are known to exist. This type of research has been strongly supported by the EU as well as the Icelandic and Norwegian research councils. The Swedish research councils tend, however, to support the extremes on this fundamental-applied scale, with VR (formerly NFR) supporting only fundamental projects in biology, while FORMAS (formerly SJFR) is increasingly demanding applied justifications for research projects.

Somewhat paradoxically, FORMAS has until recently rather funded projects in aquatic ecology related to possible ecological risks of aquaculture, rather than research into the development of sustainable aquaculture as a part of the agri-aquatic food production industry.

In spite of these facts, the FEL-group has been highly successful in obtaining individual research grants from FORMAS in the area of fish physiology and endocrinology, with justifications of the societal (aquaculture-related) importance of such research. On the other hand, FEL has still not been able to obtain larger, collaborative FORMAS grants aimed at consolidating national research in the area of sustainable aquaculture.

The FEL group has a strong track record in aquaculture-related research funded by research councils in Norway (RCN) and Iceland (AVS) through bilateral research collaborations, as well as Nordic collaborative projects financed by NI and NICe.

FEL has since long had strong collaborative ties to USA and Japan. However, since the mid-90's, the international collaborative focus has shifted to Europe, especially through active participation and coordination of a continuous string of aquaculture- related EU projects with acronyms: ENDOCONAQUA, AQUAWILD, GUTINTEGRITY, ARRDE, AQUAFUNC, WEALTH, SEAFOOD+, AQUAMAX, and currently LIFECYCLE, a major collaborative FP7 EU project including 14 partners from 8 European countries, and coordinated by FEL.

LIFECYCLE aims at contributing to support development of European fish farming. The project is a part of the EU vision that by strengthening basic and need-driven research, a strong Knowledge Based Bio-Economy (KBBE) will be created. To this end, LIFECYCLE may deliver a knowledge-base to improve competitiveness and sustainability of European aquaculture, through a combination of question- and problem-driven approaches. The focus is on development and growth, adaptation and homeostasis, immunity, and sex differentiation and puberty. Strong focus is placed on key life-stage transitions such as metamorphosis, smoltification and puberty, which often represent current production bottlenecks.

To advance current knowledge on mechanisms governing essential biological functions in fish, state-of-the-art physiological research is combined with functional genomics by leading European research groups. LIFECYCLE focuses on all major life stages of sea bass, sea bream, Atlantic salmon and rainbow trout, and some aspects of Atlantic cod and halibut biology. For these important aquaculture species, substantial resources and biological information exists which are aimed to be exploited and integrated to potentiate the overall impact.

The current/recent FEL-research in aquaculture and funding includes:

Organisation	Research project	Description
EU	**LIFECYCLE** (*www.lifecycle-fp7.eu*)	Biological knowledge-base forEuropean aquaculture.
FORMAS	**SMOLTPRO** (*www.smoltpro.science.gu.se*)	Natural smolt production.
	NFF	Non-food for food.
	LEPTIN	Physiological functions in fish.
	LIFECYCLE-Leptin	2-year postdoc.
	FISHMUCUS	First line of defence and barrier functions.
RCN Research Council of Norway	**SALPOP**	Environmental effects on smoltification.
	PUBERTY	Osmoregulation and maturation in salmon.
	HSMI	Viral infection routes in salmonids.
AVS Aukið Verðmæti Sjávarfangs (Icelandic fishery research fund affiliated to Ministry of Fisheries)	**SALCOD**	Salinity and growth in cod.
NICe	**LIFF**	Development of local feed sources for aquaculture.

UGOT was also involved in research on shellfish. To be mentioned is the NORD-OSTRON project which was funded by the EU Interreg programme (Interreg IV A Kattegat-Skagerrak) and lead by UGOT (2009–2012). The aim of the project was to develop a strategy for sustainable farming of the native European flat oyster Ostrea edulis in Scandinavia. The project was carried out in collaboration between Swedish, Norwegian and Danish universities, organizations and enterprises. The strategy report (NORD-OSTRON, 2013a) concluded a large potential for farming oyster in rural areas of Scandinavia, which are the only European area being free of the most threatening parasitic oyster diseases. Hence, Scandinavia has a unique position to develop production of flat oyster for export to Europe. Due to decreased catches and increased demand prices are increasing. However, the global production of oysters has increased, especially in Asia, from 3 million tons (1997) to 4.5 million tons in 2010 (NORD-OSTRON, 2013a). Along the Scandinavian coastline several adequate sites with good water quality for oyster farming can be identified. Further, like mussel farming in general, the production of flat oyster removes nutrients from the water thus providing a win-win effect of both producing food and improving the coastal water quality. However, a long term research and development programme of the farming technology covering all stages from hatchery to market is needed for a breakthrough of the flat oyster industry. The main challenge is to produce viable juvenile oysters, called spat, for on-growing (NORD-OSTRON, 2013a and (*www.marenovum.loven.gu.se/Nord-Ostron/index.html*)).

An additional output of the NORD-OSTRON project was a handbook for oyster farmers including oyster biology, farming technology, risks, farming permissions, economy and marketing (NORD-OSTRON, 2013b).

Further an EU funded project NEPHROPS on developing new techniques in hatchery, rearing, fishery enhancement and aquaculture for Nephrops was launched in 2012. UGOT is currently experimenting with novel baits deployed within a creel at the Underwater Observatory at Kristineberg in Gullmar Fjord, Sweden. The creel which is mounted on a steel frame, positioned at 31m depth in the fjord has a camera mounted which has revealed attractance of crustaceans (www.nephrops.eu).

A marine finfish aquaculture feasibility study at UGOT (Aquaculture Centre West) on the biological possibilities for the establishment of Swedish fish farming on the west coast has recently been published (Albertsson et al., 2012). The overall conclusion of the report was that the annual fluctuations in abiotic factors (salinity, temperature, oxygen) on the Swedish west coast did not practically allow traditional net-cage farming of the most relevant species (halibut, sole, turbot and Atlantic wolfish). A further challenge of open net-cages is the environmental impact. Hence, the report concluded that future aquaculture production on the Swedish west coast calls for new production technologies that can solve the identified challenges, i.e. possibility of adjusting/stabilizing abiotic factors as well as minimising the environmental impact.

Dr. Odd Lindahl is carrying out research on alternative uses of mussel farming, especially the use of mussel meal as an alternative ingredient in animal diets including fish. This also includes the perspective of mussel farming and removal of nitrogen and phosphorus from eutrophic water bodies, i.e. compensation farming. Such a model of compensating mussel farmers for nitrogen retrieval has recently been advocated by the Swedish Environmental Protection Board and gained certain political support.

Further, it should be noted that one of the pioneers in oceanographic modelling of environmental load from aquaculture, prof. Anders Stigebrandt, is active at UGOT, and has greatly contributed to the Norwegian legislation on aquaculture concessions.

The Agricultural University of Sweden (SLU) has previously established an Aquaculture Centre North (ACN). Aquaculture Centre West (ACW) has since been established at UGOT to gather the West coast aquaculture research under a single umbrella and thereby also creating a matching structure to ACN to facilitate national collaboration. These two centres are now connected through the National Competence Centre for Aquaculture (NCCA) to connect education, research and improve competence skills in aquaculture. The National Competence Centre is financed by the two Universities and the region.

Swedish aquaculture research is assessed to be mostly of excellent quality. However, the research efforts are still limited and fragmented and necessary infrastructures are lacking, i.e. experimental facilities (Kärlarne station is the only one existing).

There has been no initiative from funding bodies to support this challenge. Further long-term research policies on aquaculture are lacking. The Board of Agriculture (Jordbruksverket) are positive to aquaculture and try to encourage to further development. The Swedish environmental legislations are very strict and complicated making challenges to get permissions to and running aquaculture production. Additionally, the authorities in charge of aquaculture permissions and inspections are lacking competences in aquaculture. Improved education and training of inspectors in aquaculture is needed. Further, the Swedish fish farmers pay proportionally very high inspections fees compared to f. ex. agricultural farmers.

The development of aquaculture is also challenged by a critical approach to aquaculture from environmental authorities and NGOs, which also is reflected in the general public perception of aquaculture (negative environmental impact, bad health and welfare).

KSS and BTH (ACW) have over the last three years been active in planning on an annual Swedish conference on aquaculture together with SLU and the Swedish Aquaculture Organisation (SAO). These conferences have attracted 120 -180 participants with fairly equal representation from farmers, researchers and authorities.

UGOT has become more open to the public and the fish farming sector in recent years. KSS gave a presentation on alternative fish feed at a SAO yearly meeting and had very much positive feedback. The technical stage of Swedish aquaculture is rather low, the SAO is a rather small and week organisation and the general feeling is that the fish farmers lack a vision for the future development.

Overall FEL is highly active in national and international collaborations, with high external funding and high publication activity in international high-rated journals.

Perspectives for future sustainable Swedish aquaculture production:

- Aquaculture is an important food production sector and it need to improve its image to be really accepted as a sector producing healthy food
- Sweden should take greater responsibility for its own food production
- Take advantage of freshwater potential in lakes and hydroelectric dams
- Take advantage of the long coast for marine aquaculture
- Spatial planning
- Technical development (Profit and environmental efficiency)
- Multitrophic systems (fish, algae, mussels etc.)
- Focus on niche species/diversification, i.e. local species, based on public demand, red-listed species, product development – not bulk production – competition from outside, i.e. Pangasius
- SME's, utilizing existing knowledge from the fisheries sector
- Focus on sustainability – Minimize unacceptable negative environmental impact
- Research councils/financial bodies should support (stimulating without subsidizing it) to overcome hazards to development of Swedish aquaculture, i.e. technical development and increased biological knowledge
- Lack of national aquaculture infrastructures and hence applied research might be done in Norway, Iceland, Denmark or elsewhere
- Strengthen research and competence
- Education in aquaculture/improving skills

The need of specific aquaculture research in the future:

- The potential for marine aquaculture in Sweden has to be explored and the research focus should be:
  - Long term initiatives with holistic perspectives
  - New species (including marine fish and invertebrates), biology and socioeconomics, markets and product development
  - New production systems (including RAS)
  - Production ethics (welfare, environment and sustainable feeds)
- How to get value for invested research money?
  - Research and competence present in Sweden, mainly financed by European or Nordic funding
  - A long-term, substantial research program would gather and focus this research and competence
  - The newly started aquaculture centres (ACW, ACN and NCCA) will assure meeting places and transfer of knowledge from research to practice
  - A common national infrastructure for marine egg and larval development would gather research and entrepreneurs
- Why is aquaculture so limited in Sweden?
  - Early, failed attempts due to limited knowledge
  - Little structured R&D support and activities (compared with e.g. IMR- Norway, DTU-Aqua-Denmark, Hafró-Iceland)
  - Bankruptcies leading to loss of investor interest
  - Myths, mistakes and misconceptions giving aquaculture a bad reputation

- Complex legislative issues
- Incompetent permitting and expensive supervision
- No focus on marine aquaculture, sea- or land-based

Resources for research are needed to support a significant increase in the volume of aquaculture production. It is challenging to achieve funding from the research council as well as the co-financing of EFF funding as well as for the participation in international EU projects. Funding has been temporarily/short duration which limits new young scientists and new initiatives and prevents establishment of new research facilities.

List of publications (2011–2012)

Murashita K, Olderbakk-Jordal A_E, Nilsen TO, Stefansson SO, Kurokawa T, Björnsson BTh, Gamst-Moen A-G, Rønnestad I (2011): *Leptin reduces Atlantic salmon growth through the central pro-opiomelanocortin pathway*, Comp Biochem Physiol A 158: 79–86.

Fuentes EN, Björnsson BTh, Valdés JA, Einarsdottir IE, Lorca B, Alvarez M and Molina A (2011): *The IGF- I/PI3K/Akt 1 and the IGF-I/MAPK/ERK pathways in vivo in skeletal muscle are regulated by nutrition and contribute to somatic growth in the fine flounder*, Am J Physiol Regul Integr Comp Physiol 300: R1532–R1542.

Lennquist A, Asker N, Kristiansson E, Brenthel A, Björnsson BTh, Kling P, Hultman M, Larsson DGJ, Förlin L (2011): *Physiology and mRNA expression in rainbow trout (*Oncorhynchus mykiss*) after long-term exposure to the new antifoulant medetomidine*, Comp Biochem Physiol C 154: 234–241.

Johnsen CA, Hagen Ø, Adler M, Jönsson E, Kling P, Bickerdike R, Solberg C, Björnsson BTh and Bendiksen EÅ (2011): *Effects of feed energy, feeding regime and growth rate on flesh quality, connective tissue and plasma hormones in farmed Atlantic salmon (*Salmo salar L.*)*, Aquaculture 318: 343–354.

Björnsson BTh, Stefansson SO and McCormick SD (2011): *Environmental endocrinology of salmon smoltification*, Gen Comp Endocrinol 170: 290–298.

Sundell KS and Rønnestad I (2011): *Intestinal Absorption*, In: Farrell A.P., (ed.), *Encyclopedia of Fish Physiology: From Genome to Environment*, volume 2, pp. 1311–1321, San Diego: Academic Press.

Sundh H, Calabrese S, Jutfelt F, Niklasson L, Olsen RE and Sundell K (2011): *Translocation of infectious pancreatic necrosis virus across the intestinal epithelium of Atlantic salmon (*Salmo salar L.*)*, Aquaculture, 321: 82–95.

Niklasson L, Sundh H, Fridell F, Taranger GL and Sundell K (2011): *Disturbance of the intestinal mucosal immune system of farmed Atlantic salmon, (*Salmo salar*), in response to long-term hypoxic conditions*, Fish Shellfish Immunol. 31: 1072–1080.

Björnsson BTh, Lindegarth S and Sundell K (2011): *Sverige kan bli ledande i miljövänlig fiskodling*, Göteborgs- Posten, February 8th.

Kullgren A (2011): *Environmental, Nutritional and Endocrine Regulation of Metabolic Processes in Fish*, PhD thesis, Univ Gothenburg.

Segner H, Sundh H, Buchmann K, Douxfils J, Sundell KS, Mathieu C, Ruane N, Jutfelt F, Toften H and Vaughan L (2012): *Health of farmed fish: its relation to fish welfare and its utility as welfare indicator*, Fish Physiol Biochem, in press.

Trombley S, Maugars G, Kling P, Björnsson BTh and Schmitz M (2012): *Effect of restricted feeding on plasma leptin, hepatic leptin expression and leptin receptor expression in juvenile Atlantic salmon,* Salmo salar, Gen Comp Endocrinol 175: 92–99.

Fuentes EN, Einarsdottir IE, Valdes JA, Molina A, Björnsson BTh (2012): *Inherent growth hormone resistance in fish skeletal muscle is responsible for growth deficiency due to high contents of truncated GHR, impairment in the JAK2/STAT5 signaling pathway and low IGF-I expression*, Endocrinology 153: 283–294.

Kling P, Jönsson E, Nilsen TO, Einarsdottir IE, Rønnestad I, Stefansson SO, Björnsson BTh (2012): *The role of growth hormone in growth, lipid homeostasis, energy utilization and partitioning in rainbow trout: interactions with leptin, ghrelin and insulin-like growth factor I*, Gen Comp Endocrinol 175: 153–162.

Stefansson SO, Haugland M, Björnsson BTh, McCormick SD, Holm M, Ebbesson LOE, Holst JC and Nilsen TO. (2012): *Growth, osmoregulation and endocrine changes in wild Atlantic salmon smolts and post-smolts during marine migration*, Aquaculture 362–363: 127–136.

Johnsen CA, Hagen Ø, Solberg C, Björnsson BTh, Jönsson E and Bendiksen EÅ (2012): *Seasonal changes in muscle structure and flesh quality of 0+ and 1+ Atlantic salmon (*Salmo salar L.*): Impact of feeding and the role of ghrelin*, Aquacult Nutr 362–363: 264–272.

Björnsson BTh, Einarsdottir IE, Power DM (2012): *Is salmon smoltification an example of vertebrate metamorphosis? Lessons learnt from work on flatfish larval development*, Aquaculture, in press.

Gadan K, Marjara I Singh, Sundh H, Sundell K and Evensen Ø (2012): *Slow release cortisol implants result in impaired innate immune responses and higher infection prevalence following experimental challenge with infectious pancreatic necrosis virus in Atlantic salmon (*Salmo salar*) parr*, Fish Shellfish Immunol, in press.

Frøiland E, Jobling M, Björnsson BTh, Kling P, Ravuri CS, Jørgensen EH (2012): *Seasonal appetite regulation in the anadromous Arctic charr: Evidence for a role of adiposity in the regulation of appetite but not for leptin in signalling adiposity*, Gen Comp Endocrinol 178: 330–337.

Sundt-Hansen L, Einum S, Neregård L, Björnsson BTh, Johnsson JI, Fleming IA, Devlin RH, Hindar K (2012): *Growth hormone reduces growth in free-living Atlantic salmon fry*, Func Ecol 26: 904–911.

Raven PA, Sakhrani D, Beckman B, Neregård L, Sundström LF, Björnsson BT, Devlin RH (2012): *Growth and endocrine effects of recombinant bovine growth hormone treatment in non-transgenic and growth hormone transgenic coho salmon*, Gen Comp Endocrinol 177: 143–152.

Fuentes EN, Kling P, Einarsdottir IE, Alvarez M, Valdés JA, Molina A, Björnsson BTh (2012): *Plasma leptin and growth hormone levels in the fine flounder (*Paralichthys adspersus*) increase gradually during fasting and decline rapidly after refeeding*, Gen Comp Endocrinol 177: 120–127.

Sundell K and Sundh H (2012): *Intestinal fluid absorption in anadromous salmonids: importance of tight junctions and aquaporins*, Front. Phys. 3: 388, doi: 10.3389/fphys.2012.00388.

Sandblom E, Djordjevic B, Sundh H, Seth H, Sundell K, Lines JA and Kiessling A (2012): *Effects of electric field exposure on blood pressure, cardioventilatory activity and the physiological stress response in Arctic char,* Salvelinus alpinus L, Aquaculture. 344–346: 135–140.

Chalmers

Participants

Ass. Prof. *Torsten Wik* (TW)
Thomas Nilsson (TN), MISTRA
Alfred Jokumsen (AJ), MISTRA WGA

Torsten Wik (TW) is educated Chem. Engineer and is currently employed as Assoc. Prof. in Automatic Control at Chalmers. His Ph.D. (1999) was on environmental engineering: *Modelling the dynamics of fixed biofilm reactors – with focus on nitrifying trickling filters*.

The main interests of TW are modelling processes in Recirculation Aquaculture Systems (RAS), i.e. wastewater treatment. This means development of dynamic mathematical models of system performance. TW research is mainly funded by Chalmers and by regional funds. The research group includes 1 research scientist (TW) and 1 Ph.D. student.

TW has modelled and programmed a RAS simulator in cooperation with SLU (Umeå). He has simulated different configurations, food and species (Clarias, Salmon, Tilapia and Pangasius). TW was involved in the design and development of a large pilot indoor RAS plant (20 tonnes/year), running 2002–2005, but due to difficulties to get funding for academic RAS research at that time, this activity stopped.

TW published the ideas behind the simulator in (Wik et al., 2009. Aquaculture 287, pp. 361–370).

TW has been representative in Nordic RAS since the start (2011). The Nordic RAS may be a platform for future international cooperation on recirculation technology and farming. Since then TW has established contact with well-equipped RAS plants on Ljusterö and in Östergötland for experimental cooperation and also contact with the group around Bodecker having the RAS plant in Öved and the new plants in Alnarp (SLU).

The current research related to aquaculture at Chalmers includes:

- Dynamic modelling and simulation of RAS
- Effects and interactions between feed, faeces and the water treatment.
- Configurations of RASs for robustness
- New WWTP processes such as high shear force granulation to avoid the need for cumbersome particle separation.
- Antioxidants in fish
- Oxidation of marine fatty acids in intestines
- Micro-algae for industrial bioprocesses

As to the potentials of future development of Swedish aquaculture and associated research TW identified the following issues:

- Farming in oligotrophic lakes and hydropower reservoirs in northern Sweden as well as large scale marine production, e.g. mussels on the west coast removing nutrients from the water
- Due to environmental considerations further aquaculture production requires waste water treatment, i.e. recirculation technology
- Utilisation of waste heat may improve the profitability of the production and further diversify to farming warm water species

- Recirculation aquaculture systems may even disconnect the aquaculture production from the external environment, i.e. no environmental impact developing innovative solutions to waste treatment through the mechanical and biological processes of the system
- Investigation of dynamic interplay between the waste water treatment, feed and fish in RAS
- TW was in favour of combinations of herbivorous warm water tropical species with locally established high valued species, such as pike-perch and perch using RAS – and reuse of nutrients
- Different groups (UGOT, SLU, KTH, Chalmers etc.) have started to communicate, collaborate and become more active, especially in recirculation systems (KTH and Chalmers).

TW has a significant knowledge in modelling dynamics of waste water treatment in RAS and may be a key partner for future aquaculture research in high tech aquaculture systems.

The Swedish Agency for Marine and Water Management (SwAM)

Participants

Head of good water quality *Kajsa Berggren* (KB)
Coordinator (Aquaculture) *Josefin Walldén* (JW)
Management of biological diversity *Sofia Brockmark* (SB)
Research dep./Managem. Environ. Monitoring *Erland Lettevall* (EL)
Axel Wenblad (AW), MISTRA WGA
Thomas Nilsson (TN), MISTRA
Alfred Jokumsen (AJ), MISTRA WGA

The Swedish Agency for Marine and Water Management (SwAM) – **Havs och Vattenmyndigheten** (HaV) – is a governmental authority monitoring Swedish water bodies (seas, lakes and streams). SwAM is preparing guidelines for the County administrative boards and the municipalities, i.e. making guidelines for officers giving permissions/inspecting aquaculture farms. Further SwAM is responsible for the fishery legislation (restocking) and the overall responsibility for Common Fisheries Policy (CFP).

SwAM was established 1st July 2011 as it took over water related tasks from **Fiskeriverket** and the coastal zone from the Swedish Environmental Protection Agency. SLU took over research and data collection on fish from Fiskeriverket, while the aquaculture issues were transferred to **Jordbruksverket**. However, grey zones still exists between Jordbruksverket and SwAM. F. ex. SwAM makes guidelines for the municipal officers giving permissions/inspecting aquaculture farms.

SwAM has 4 departments:

1. Science Affairs (monitoring the environment and data collection on fish/fisheries, coordinating research needs, economic analyses etc.)
2. Planning (EU Marine Strategy Framework Directive, EU Water Framework Directive, EU Common Fisheries Policy, marine spatial planning etc.)
3. Policy Implementation (protection of species and habitats, environmental and Fishing interests, eutrophication, permits and licences etc.)
4. Inspection and Enforcement (Fishery inspections and fishing bans, sanctions for violations in the fishing profession, legal support etc.)

One of the challenges for aquaculture development is many authorities to be involved:

- The Board of Agriculture (Jordbruksverket – Fish health)
- National Food Agency (Livsmedelsverket)
- The Swedish Agency for Marine and Water Management (Havs- och
- Vattenmyndigheten)
- National Veterinary Institute (SVA)
- Counties (Länsstyrelserna)
- Municipalities (Kommunerna)

However, SLU has an environmental project that should provide a tool to facilitate the process through the authorities.

SwAM has the following overall approach in relation to aquaculture:

- Basically aquaculture development implies no net discharge of nitrogen and phosphorus to the Baltic Sea/Östersjön
- The overall approach is to aim for aquaculture feed based on fish and other organisms from the Baltic Sea for aquaculture production in the Baltic Sea area
- Aquaculture is developed sustaining the good veterinary health status in farmed as well as wild stocks
- Prophylactic treatment of farmed fish and good farm management (robust stocks) is prioritized to prevent disease
- Efficient support from the authorities to develop a sustainable aquaculture business
- Attention should be paid to native species and unique genetic strains as well as restrictive import and restocking

SwAM focused the following environmental issues (challenges) related to aquaculture development:

- Nutrients (Nitrogen, phosphorus, organic matter)
- Fish feed (sourcing ingredients, feed utilization, waste)
- Spreading of disease
- Chemicals and antibiotics
- Leisure (people not wanting aquaculture as their neighbour during free time)

The main challenge for aquaculture development is the request of environmental efficient production and fulfilling the BSAP.

SwAM experience a good relationship to the aquaculture sector and good cooperation with The Board of Agriculture.

Reasons for a stagnating aquaculture production maybe due to:

- Economic concerns, i.e. risk of losing the production due to disease
- Complicated and strict environmental legislation
- Infrastructure missing
- Need of better education/training of persons in the aquaculture decision system
- Aquaculture is handled in the environmental legislation as “a dangerous activity”

- Research should be more strategic/applied. Much research is good and relevant, but better connections between the challenges in the sector and the research activities is needed
- Better coordination of administration of the sector is needed

The InterReg project AQUABEST and the included Feasibility study was mentioned as a good model for Swedish farming, i.e. spatial planning.

The Swedish Aquaculture Organisation (SAO)

Participants

Henrik Hammar (HH), Chairman
Axel Wenblad (AW), MISTRA WGA
Alfred Jokumsen (AJ), MISTRA WGA

The Swedish Aquaculture Organisation (SAO) – **Vattenbrukarnas Riksförbund** (VRF) is a national aquaculture organisation as a spokesman to support the interests of the Swedish aquaculture farmers to the authorities and the society and promote the development of aquaculture in Sweden. The members (60–70) include producers of fish and shellfish for human consumption, restocking and recreational fishery.

Henrik Hammar (HH) is a lawyer and has many years of political experience. He was leading the establishment of region Skåne and the Baltic Sea Committee.

The organisation has no secretariat – only a board. That means that the organization can give no support/consultancy for the farmers. However, to fulfil the obligations in the strategy a stronger SAO and a secretariat is needed. HH hopes for financial support through EFF.

Aquaculture must be taken seriously, but the Board of Agriculture (BA) – Jordbruksverket – is putting focus on aquaculture and is doing a good job to promote aquaculture and SOA has expectations that BA may facilitate this positive development by:

- Sustained focus on potentials for development of Swedish aquaculture
- The policies shall reflect the conclusions of *Det växande vattenbruket* (SOU, 2009) and the strategy *Svenskt vattenbruk – en grön näring på blå åkrar. Strategi 2012–2020* (Jordbruksverket, 2012c).
- Promote education and training of skilled persons to be able to perform the specific tasks in the farming sector in a professional and efficient way – along the whole production chain including inspectors and control authorities
- Simplification of the legislations and administration of the sector
- Spatial planning and diversification of aquaculture – local productions – new jobs

HH in particular mentioned Jämtland as a county where much effort is being done to develop aquaculture.

There is a need of research/development and knowledge in:

- New farming technologies for environmental efficient productions
- Feeds – nutrient loop concept
- National breeding programme
- New species

The current research issues at UGOT and SLU are OK, but a link/management of the research and the needs of the farming sector are missing. No formal contacts between researchers and the farming sector on specific projects.

HH expects that the established aquaculture centres (West-North-East) and the national centre will provide a tool/platform for stronger management and coordination of Swedish aquaculture research, i.e. a kind of an "Aquaculture institute without walls".

In the strategy the farming sector has taken responsibility of specific tasks and the relevant authorities have taken responsibilities for other specific tasks to fulfil the common efforts to further develop Swedish aquaculture. HH believes in the strategy will work.

The most important message from SOA is: Will the strategies of EU and the Swedish government related to the need of higher global aquaculture production be put into real action?

The Board of Agriculture (BA)

Participants

Ulrika Bergman (UB), the Board of Agriculture, Head of Aquaculture
Alfred Jokumsen (AJ), MISTRA WGA

The Board of Agriculture (BA) – **Jordbruksverket** – is the Government's expert authority in matters of agri-food policy, and is responsible for the agricultural and horticultural sectors, which also includes fisheries and aquaculture, i.e. separate division of aquaculture. BA has approximately 1,200 employees of which about 650 persons are working at the head office in Jönköping.

150 persons are placed in southern and central Sweden dealing with environmental issues, water, seeds, inspection, and livestock registers. Slightly more than 400 persons work at district veterinary stations all over Sweden.

BA is dominated by the agricultural sector and requested expertise in aquaculture is currently based on knowledge and experience from agriculture. However, there are basic differences in farming terrestrial and aquatic animals.

Only one organic fish farm exists in Sweden. Apparently, the sector is not interested in organic fish farming as they perceive organic as environmentally difficult by using recirculation technology. However, this testifies insufficient knowledge about the organic regulations on aquaculture (KRAV, EU).

The inspection fees for fish farms are extremely high in Sweden, i.e. size of about SEK 300,000 for 3,000 t production, while much lower fees for the agricultural sector. BA has prepared a proposal for more fair fee rating for aquaculture.

AJ drew the attention to the wording "environmentally hazardous production" about aquaculture in the Swedish environmental legislation. UB agreed that it was an inappropriate wording and expressed hope that a positive development of Swedish aquaculture may change this.

BA is improving knowledge and dissemination about aquaculture to the public, cf. website: *www.jordbruksverket.se*.

BA has overall good relationships to and cooperation with the key stakeholders, i.e.

- Fish farmers organisation (Vattenbrukarnas Riksförbund)
- Havs- och Vattenmyndigheten (HaV). However, as their responsibilities have been split up, grey zones of responsibility still exists
- BA has a good cooperation with WWF and Naturvårdsforeningen. The Organisations joined the strategy work. They are worried about pollution, but have accepted that aquaculture has come to grow. They want to influence the process to be co-players in a sustainable development, which is positive.

- All have a common understanding of fulfilling the Baltic Sea Action Plan (BSAP). UB assess the Swedish aquaculture research as good and relevant for the sector.

However, the research is on a higher level than the day-to-day life of the aquaculture farmers. The farmers do not know how to utilize the knowledge. The annual conferences seem not to affect the farmers as she perceived researchers and farmers speaking different languages.

BA handles the European Fisheries Fund (EFF), i.e. evaluation of applications. There are apparently some misunderstandings whether researchers can apply for funding's at EFF. However, this is possible, f. ex. project cooperation with the Fish Farmers Ass. and research inst. (universities) on a specific farming related issue.

UB pointed out the research to be addressed:

- Fish feed (nutrient efficient fish feed)
- Innovative techniques to decrease discharges
- Disease control and preventive measures
- Biosecurity: hygienic routines on the farms – minimize spreading of diseases – currently a real risk!
- New species: niche products – but still Swedish bulk production will dominate.

Further UB stressed the need of better education/training of authority officers/ inspectors. Their competences are currently imperfect.

Shellfish Producers Organisation (SPO)

Participants

Björn Lindblad (BL), working in the secretariat for the Swedish Shellfish Producers' Organisation
Alfred Jokumsen (AJ), MISTRA WGA

The Shellfish Producers Organisation (SPO) was established in 2007. As an independent organisation it might achieve better support through the *European Fisheries Fund* (EFF). Thus the administrative costs might be covered by 60, 40 and 20 %, respectively of the costs during the first 3 years of operation. Additionally, support might be achieved for 5 years in proportion to the contribution to the total national aquaculture production.

The organisation counts 12 members on the west coast. The total annual production amounts currently to about 1,500 t of shellfish for consumption. BL has been employed ¼ time and makes the secretariat.

One of the 12 producers – Scanfjord – produces almost the whole production, about 1,490 t, so the remaining 11 members are small producers; even some of them have today no production.

Mussel meal scientist and producer Odd Lindahl uses by-products and mussel meat from Denmark.

It is no problem to get permissions for production (no feeding). However, the real challenge is to get dispensation from shoreline protection regulation for the 300 m limit distance from the coast (leisure houses, tourism).

BL found that researchers and aquaculture producers "lives their own lives apart from each other", i.e. with no linkage. BL expressed that he can´t see that the researches have much interest in cooperation with the producers. Linkage is missing between research and production. Important to show mutual respect between researchers and the producers. Lindblad also means that there is a big difference between what the producers are working with and interested in and what can be questions for scientists.

However, in case of cooperation BL found that researchers preferred to cooperate with a single farmer as better to manage the project in the way the researchers preferred than cooperating with and making an agreement with a whole sector.

BL perceived aquaculture conferences to be one-way communication. No presentations from the producers. However, some responsibility for this may also be the producers.

The majority of the Swedish production is sold in the Swedish market. A small amount is exported to Norway, while also some import from Denmark. Scanfjord is KRAV certified and is aiming to be obtaining the MSC label. However, improved marketing is needed. The farmers are good in producing, but the problem is to sell their products.

About 85 t wild mussels are caught by dredging. Dredged mussels are red-listed; however it does not affect consumers' willingness to buy.

BL found that Henrik Hammar, The Swedish Aquaculture Organisation (SAO) had strengthened the sector and a merger between SOA and SPO was under consideration.

BL found that aquaculture miss credibility in the public, as fish farming was connected with pollution, which fits with the wording "environmentally hazardous activity" in the environmental legislation. Accordingly, the sector needs help and support from the researchers to provide scientific data that the producers take care of the environment.

Further aquaculture has to be accepted as an equal food producing sector as the agricultural sector.

BL assessed mussel meal as a niche product and is afraid that it will be too expensive to be a competitive feed ingredient in the Swedish aquaculture.

The Agricultural University of Sweden (SLU)

Participants

Anders Kiessling (AK), Professor
Alfred Jokumsen (AJ), MISTRA WGA

The Agricultural University of Sweden (SLU) – **Sveriges Lantbruks Universitet** (SLU) refers to the Ministry of Rural Affairs. By the split of Fiskeriverket (2011) 160 persons were transferred to SLU. Aquaculture research at SLU is currently under the umbrella of Department of Wildlife, Fish and Environmental Studies (*Institutionen för Vilt, Fisk och Miljö*). Totally 16 persons are employed within aquaculture, but associated are as well resource persons within animal breeding, food safety, nutrition of monogastric animals etc.

However, aquaculture related issues are as well included in the research at Department of Aquatic Sciences and Assessment, e.g. ecological status classification according to the Water Framework Directive.

By regulation letter the Min. Rural Aff. has given SLU the task to include the following fields of aquaculture in its activities:

- **Teaching.** SLU address' teaching at four levels. SLU is guarantor for teaching and content of the education in environmentally friendly aquaculture (*Yrkeshögskole* level). The education is owned by Väddö Folkhögskola, and is 1 year including 16 weeks of practical exercises. The academic education includes B.Sc. where aquaculture is included at appropriate courses as e.g. animal husbandry, veterinarian medicine and natural resources. SLU also gives an introductory course in aquaculture of 15 ects, as distance learning with three physical meetings, focusing study visits. SLU has no specific M.Sc. courses in aquaculture yet. However, SLU is involved in joint Nordic initiatives, e.g. AquaFood M.Sc. program and NOVA M.Sc. courses in aquaculture. SLU is also an active partner of the EU project for aquaculture and fisheries education, AquaTnet. SLU also delivers 2–5 Ph.D. theses in aquaculture yearly.

- **Research** (see below)
- **Advisory for the authorities/industry.** SLU is an active partner of the Aquaculture Centre North (ACN), Kälarne research station, responsible for handling the two on going breeding programs for Arctic char and rainbow trout. SLU is also a partner of Aquaculture Centre East (ACE), focusing closed systems. The National Competence Centre for Aquaculture (NCCA) benefits from the joint competences at the regional aquaculture centres. In addition SLU is responsible for the fish component of the joint industry-academic consortium for utilising waste heat for food production. This involves direct contact and engagement with the industry and regions supporting and advising, based on own and others research. SLU is involved in national advisory activities with authorities and industry related to aquaculture. SLU has extensive international networks in the field of aquaculture, including Nordic cooperation, EU and overseas. SLU is also engaged in the National advisory board of The Swedish Agricultural Board's health and aquaculture groups.

The activities at SLU include:

- New and sustainable feed sources based on locally recaptured nutrients
- Food safety and animal welfare in the production system, including effect of new feed sources
- Breeding, including on-going breeding programs and utilization of genetic capacity in new species with special attention to robustness and interaction with new feed sources, i.e. > 30 years breeding program at Kälarne on Arctic char and Rainbow trout
- Disease risk assessment and control (Fish Health Centre at Ultuna)
- Environmental effects of fish farming with special emphasize on identifying and characterize suitable farming sites of open systems:
  - Nutrient pathways in unnatural oligotrophic water systems
  - Genetic contamination of wild fish populations
  - Disease risks by a growing industry in presently low risk inland locations
  - Environmental impact of assessment of localisation of a cage farm, i.e. developing into an environmental service
  - Ecosystem effects of fish farming in hydro power water dams, i.e. following nutrients discharged from fish farming into the ecosystem by means of stable isotopes
  - Farming potential in hydro power water dams associated to the AQUABEST project (Jämtland region)
- Development of "new" and local aquaculture species, i.e. pike perch, perch, turbot etc.
  - Focus on larvae rearing and reproduction
  - Disease risk assessment
  - Nutrition
  - Rearing technology
- Rearing technology, building a joint competence between biological (SLU) and technical (KTH) competences. Together with Norwegian (UMB) and Danish partners
- Fish as food, especially bioactive components like fatty acids and food safety with new feed sources

- Market (together with regional and industry interest) and consumer perception-interactions – environmental friendly prod./using excess heat
- Industry implementations (specially engage in ACN and ACE. ACN = Jämtland while ACE is driven by Öster Götland together with Kalmar, Blekinge and Skåne and specifically focus industry and R&D in using excess heat and land based system.

Sustainable aquaculture may imply the "closing the nutrient loop" concept: Recapturing of nutrients in the Baltic Sea transformed into feed ("Baltic Blend" for farming fish in f ex. Northern oligotrophic lakes ("Robin Hood"), i.e.

- Fish meal/fish oil detoxified (PCB/dioxin) from industrial/management fishing in the Baltic Sea and its water shed
- Using mussel meal (caught N & P from eutrophic Baltic Sea) as dietary protein source
- Using microbial meal from microbes farmed on society organic side flows as dietary protein source and thereby utilise fish farming as the "missing" link in the closing of the nutrient loop of modern food production. FORMAS has funded a project in the area: *Microbes as a sustainable feed source to farmed fish*, as a strategic multi-disciplinary and cross university research project (SLU and UGOT). The project focuses especially the nutritional quality of yeast as a fish feed ingredient and also link to the AQUABEST project regarding "the nutrient loop" in the Baltic Sea.

  Further, SLU is partner of an EFF (European Fishery Fond) project in building a demonstration plant utilising live microbial feed.

The research infrastructure related to aquaculture research at SLU includes:

- **Kälarne:** Breeding and long term feed x genetic studies on cold water species (Arctic char and Rainbow trout)
- **Älvkarleby:** Individual fish laboratory for studies on Nutrition, welfare and health in salmonids
- **Oskarshamn:** A R & D-centre and aquaculture industry park at the nuclear power plant and reusing warm water for farming new species (pike perch, perch, turbot etc) in closed systems are planned together with Aspö Laboratory, NOVA Högskole Centrum, Oskarshamn, industry and Oskarshamn's municipal.
- **ESS/Lund/Alnarp:** European Spatial Source (ESS) joint project of Sweden and Denmark, building an accelerator at Lund. It is an EU project, including 43 countries and it is expected to be a centre of excellence in physics concerning structure of inner material. Further, it will be a "green" centre using surplus heat (estimated to 120 GW a year, and half in luke warm water (< 55 °C)). Urban food production ("Heat to food") using integrated and multi-trophic closed systems are presently being evaluated as a centre of scientific excellence and thereby constitute one of ESS long term research areas for waste heat.

A growing aquaculture industry in Sweden including new species implies developed market channels to sell the products – preferably on the domestic market. To get the consumer acceptance of eating Swedish fish requires focused dissemination of the way of sustainable production – environmentally friendly – reuse of nutrients and waste heat (Green energy) – consumer acceptance.

There is a great potential for further cooperation between research institutions in Sweden – even competition will exist it may improve utilization of research funds. However, improved cooperation is anticipated through the platforms of the research centres (West, North and East) as well as the National Competence Centre.

As to SLU the future need of aquaculture research includes

- Nutrient recapture via farming of mussels
- Incorporation of nutrients in pelagic food webs as contribution to the restoration of oligotrophic water systems
- Development of new feed sources, with special emphasis on microbial sources (including potential immune stimulating effects) and aquatic catch crops, as blue mussels, detoxified fish meal/oil and freshwater white fish from ecological management fishing
- Alternative sources of marine lipids. SLU, via Lipid center at Alnarp, is actively involved in GMO work with Rapeseed to produce EPA and DHA in large quantities
- Production of robust and disease free larvae of high genetic potential, in particular species with small eggs and larvae needing live starter feed. The issue is focus by combining competences at SLU, SVA (Veterinärinstitutet) and KTH (Kungliga Tekniska Högskolan). Further SLU and SVA is collaborating with the private health service and the Agricultural Board to evaluate the possibility to create a *Fish health centre* at Ultuna, Uppsala, as both the SLU and SVA activities of fish health already is located here.

The integration of research results into practical business is progressing. In Figure 3 is indicated the interrelationship between *Region-Aquaculture Centre-business* through-out the country and *Universities SLU/UGOT-National Competence Centre* on one side and the governmental authorities *Min. Rural aff./Board of Aquaculture* on the other. All nodes are established as virtual centres, North (cold water fish in open systems), West (marine systems) and East (closed and semi closed systems, with or without synergy with waste heat (Anders Kiessling, pers. comm.). Extension of this integration into future multidisciplinary Research and Development strategies/platforms may improve value for invested money in Swedish Aquaculture.

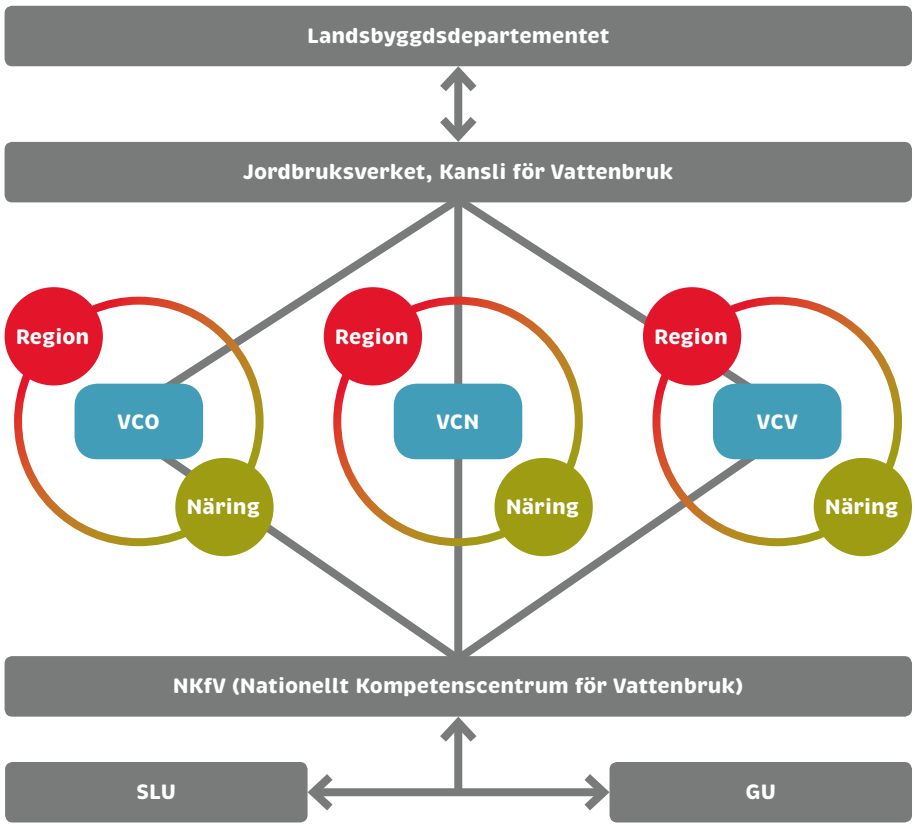


FIGURE 3 Illustrating the present concept now discussed between SLU, regions, Board of Agriculture and Ministry of Rural Affaires. ANDERS KIESSLING

There is a great need of education for people in the industry. *Yrkeshøgskolan* in Jämtland has a 1 year farming education at high school level including disease, farming practice, feed, nutrition etc.. SLU, together with its partner SVA and UMB (Norway) is responsible for securing quality of the biological, veterinarian medicine and production subjects, while Väddö has the responsibility to secure quality of economy, marketing and the practical exercises.

Overall SLU aquaculture research reflects highly activity in national and international collaborations, with high external funding and high publication rates in international high-rated journals.

The research partly reflects the challenges of the industry and authorities, but also future challenges of turning aquaculture into an environmentally friendly production contributing to the future global food security and rural development. In line with this a main target is future feed sources including a special attention to farmed fish.

Another important task of SLU is development of the two active breeding programs and to assist in programs aimed at new species. However, the farmers have not always agreed on the breeding programme, but in recent years the Arctic char producers have changed their mind as they see the progress in their production. Also trout farmers are beginning to see the perspectives.

List of publications (2011–2012):

Trattner, S. Ruyter, B. Østbye, T. K. Kamal-Eldin, A. Moazzami, A. Pan, J. Gjøen, T. Brännäs, E. Zlabek, V. Pickova, J. (2011): *Influence of dietary sesamin, a bioactive compound on fatty acids and gene expression of some lipid regulating genes in Baltic Atlantic salmon (*Salmo salar L.*) juveniles*, Physiol. Res. 60: 125–137. Number of citations: 2.

Lapa Guimaraes, J. Trattner, S. Pickova, J. (2011): *Effect of processing on amine formation and lipid profile of cod roe*, Food Chemistry 129(3): 716–723. Number of citations: 0.

Schiller Vestergren, AL. Trattner, S. Mraz, J. Ruyter, B. Pickova, J. (2011): *Fatty acids and gene expression responses to bioactive compounds in Atlantic salmon (*Salmo salar L.*) hepatocytes*, Neuroendocrinology Letters 32(S2): 41–50. Number of citations: 0.

Schiller Vestergren, AL. Trattner, S. Pan, J. Johansson, P. Kamal-Eldin, A. Brännäs, E. Moazzami, AA. Pickova, J. (2012): *The effect of combining linseed oil and sesamin on the fatty acid composition in white muscle and on expression of lipid-related genes in white muscle and liver of rainbow trout (*Oncorhynchus mykiss*)*, Aquaculture International 1–17. Number of citations: 0.

Wagner, L. Zlabek, V. Trattner, S. Zamaratskaia, G. (2012): *In vitro inhibition of 7-ethoxyresorufin O-deethylase (EROD) and p-nitrophenol hydroxylase (PNPH) activities by sesamin in hepatic microsomes from two fish species*, Molecular Biology Reports, Accepted.

Schiller Vestergren, AL. Wagner, L. Pickova, J. Rosenlund, G. Kamal-Eldin, A. Trattner, S. (2012): *Effect of sesamin on dietary fatty acid composition and gene expression profile in Atlantic salmon (*Salmo salar L.*) fed different n-6/n-3 fatty acid ratios*, Lipids, 47(9), 897–911.

Djordjevic, B., Kristensen, T., Øverli, Ø., Rosseland, B.O. and Kiessling. A. (2011): *Effect of nutritional status and sampling intensity on recovery after dorsal aorta cannulation in free swimming Atlantic salmon (*Salmo salar L.*)*, Fish Biochem. Physiol. DOI 10.1007/s10695-009-9362-2, in press.

Anders Karlsson, Bjørn Olav Rosseland, Helgi Thorarensen and Anders Kiessling. (2011): *Changes in arterial oxygen tension and blood physiological status in resting and unrestrained Arctic charr (*Salvelinus alpinus*) exposed to mild hypoxia and hyperoxia*, Fish Physiol Biochem, in press.

Karlsson, A., Heier, L. S., Rosseland, B. O., Salbu, B. and Kiessling, A. (2011): *Changes in arterial PO2, physiological blood parameters and intracellular antioxidants in free swimming Atlantic cod (*Gadus morhua*) exposed to varying levels of hyperoxia*, Fish Physiol. Biochem. 37: 249–258.

Karlsson, A., Rosseland, B-O., Massabuau, J.C. and Kiessling, A.: *Pre-anaesthetic metomidate sedation delays the stress response after caudal artery cannulation in Atlantic cod (*Gadus morhua*)*, Fish Physiol and Biochem., In press, IHA.

Johan Bankeforsa, Marta Kaszowskaa, Christian Schlechtriemb, Jana Pickovab, Eva Brännäs, Lars Edebod, Anders Kiessling and Corine Sandströma: *A comparison of the metabolic profile 1 on intact tissue and extracts of muscle and 2 liver of juvenile Atlantic salmon (*Salmo salar L.*); 3 – Application to a short feeding study,* Food Chemistry, 129: 1397–1405 VBR.

Inger Hilde Zahl & Anders Kiessling … : *Anaesthesia of farmed fish: implications for welfare*, Fish Physiol Biochem, special issue, in press, IHA VBR.

Da, C. T., Hung, L. T., Berg, H. Lindberg, J.E. Lundh, T. (2011): *Evaluation of potential feed sources, and technical and economic considerations of small-scale commercial striped catfish (*Pangasius hypothalamus*) pond farming systems in the Mekong Delta of Vietnam*, Aquaculture research, published on line, DOI: 10.1111/j.1365–2109.2011.03048.x.

Da, C. T., Lundh,T., Lindberg, J.E. (2012): *Evaluation of local feed resources as alternatives to fishmeal on growth performance, feed utilization and biological indices of striped catfish (*Pangasianodon hypophthalmus*) fingerlings,* Aquaculture, Volumes 364–365, 5 October 2012, Pages 150–156.

Da, C. T., Lundh,T., Lindberg, J.E. (2012): *Digestibility of dietary components and amino acids in plant protein feed ingredients in striped catfish (*Pangasianodon hypophthalmus*) fingerlings*, Aquaculture Nutrition (accepted).

Da, C. T., Lundh,T., Lindberg, J.E. (2012): *Digestibility of dietary components and amino acids in animal and plant protein feed ingredients in striped catfish (*Pangasianodon hypophthalmus*) fingerlings*, Aquaculture nutrition, submitted.

Trattner, S., Ruyter, B., Østbye T. K., Moazzami, A., Pan, J., Gjøen, T. Brännäs, E., Zlabek, V. Pickova, J. (2011): *Effects of dietary sesamin in wild Baltic salmon (*Salmo salar L.*) juvenile muscle and liver*, Physiological Research 60: 113–124.

Sampels, S., Pickova, J. (2011): *Comparison of two different methods for the separation of lipid classes and fatty acid methylation in reindeer and fish muscle*, Food Chemistry 128: 811–819.

Lapa-Guimarães, J., Trattner, S., Pickova, J. (2011): *Effect of processing on amine formation and the lipid profile of cod (Gadus morhua) roe*, Food Chemistry 129: 716–723.

Lau, D.,Vrede, T., Pickova, J., Goedkoop, W. (2012): *Fatty acid composition of consumers in boreal lakes – variation across species, space and time*, Freshwater Biology 57, 24–38.

Schiller Vestergren, AL., Trattner, S., Mraz, J., Ruyter, B., Pickova J. (2011): *Fatty acids and gene expression responses to bioactive compounds in Atlantic salmon (*Salmo salar L.*) hepatocytes*, Neuro Endocrinol Lett. 2011 Nov 21;32 (Suppl 2): 41–50.

Ahmed, M., Moazzami, AA., Andersson, R., Pickova, J. (2011): *Varying quality of fish oil capsules: fatty acids and tocopherol*, Neuro Endocrinol Lett. 2011 Nov 21;32 (Suppl 2): 37–40.

Bankefors, J., Kaszowska, M., Schlechtriem, C., Pickova, J., Brännäs, E. , Edebo, L., Kiessling, A., Sandström, C. (2011): *A comparison of the metabolic profile on intact tissue and extracts of muscle and liver of juvenile Atlantic salmon (Salmo salar L.) – Application to a short feeding study*, Food Chemistry 4: 1397–1405.

Adámkova, V., Kacer, P., Mraz, J., Suchanek, P., Pickova, J., Kralova-Lesna, I., Skibova, J., Kozak, P., Maratka, V. (2011): *The consumption of the carp meat and plasma lipids in secondary prevention in the heart ischemic disease patients,* Neuro Endocrinol Lett. 2011 Nov 21;32 (Suppl 2): 17–20.

Mraz, J., Pickova, J., (2011): *Factors influencing fatty acid composition of common carp (*Cyprinus carpio*) muscle,* Neuro Endocrinol Lett. 21;32 (Suppl 2): 3–8.

Strandvik, B., Chen, Y., Dangardt, F., Eriksson, S., Friberg, P., Garemo, M., Pickova, J. (2011): *From the Swedish to the Mediterranean diet and the omega-6/omega-3 balance*, World Rev Nutr Diet; 102: 73–80.

Schiller Vestergren, A., Wagner, L., Pickova, J., Rosenlund, G, Kamal-Eldin, A., Trattner, S. (2012): *Sesamin modulates gene expression without corresponding effects on fatty acids in Atlantic salmon (*Salmo salar L.*)*, Lipids 47: 897–911.

Sanseverino, A.M. , Bastviken, D., Sundh, I., Pickova, J., Enrich-Prast, A. (2012): *Methane carbon supports aquatic food webs to the fish level*, PLoS ONE 7, issue 8, 7 August 2012, article number 42723.

Vestergren, A.S., Zlabek, V., Pickova, J., Zamaratskaia, G. (2012): *Tolbutamide hydroxylation by hepatic microsomes from Atlantic salmon (*Salmo salar L.*)*, Molecular Biology Reports 39: 6867–6873.

Burkina, V., Zamaratskaia, G., Randak, T., Li, Z.H., Fedorova, G., Pickova, J., Zlabek, V. (2012): *Verapamil does not modify catalytic activity of CYP450 in rainbow trout after longterm exposure*, Ecotoxicology and Environmental Safety 79: 148–152.

Mráz, J., Máchová, J., Kozák, P., Pickova, J. (2012): *Lipid content and composition in common carp – optimization of n-3 fatty acids in different pond production systems*, Journal of Applied Ichthyology 28: 238–244.

Vestergren, A.S., Trattner, S.Pan, J., Johnsson, P. Kamal-Eldin, A. Brännäs, E., Moazzami, A.A., Pickova, J. (2012): *The effect of combining linseed oil and sesamin on the fatty acid composition in white muscle and on expression of lipid-related genes in white muscle and liver of rainbow trout (*Oncorhynchus mykiss*)*, Aquaculture International, 17pp, in press.

Royal Institute of Technology (KTH)

Participants

Bjørn Frostell (BF), Associated Professor
Alfred Jokumsen (AJ), MISTRA WGA

Björn Frostell (BF) is an associate professor and docent in Industrial Ecology at Dep. of Industrial Ecology at Royal Institute of Technology (KTH) – Kungliga Tekniska Högskolan – in Stockholm. BF has a background as Civil Engineer and has been working with biogas and waste water treatment in the sugar industry (energy efficiency).

Industrial ecology may be defined as “the science of sustainability”, as it is an interdisciplinary framework for designing and operating industrial systems as liv-

ing systems interdependent with natural systems. It seeks to balance environmental and economic performance within local and global ecological constraints, including climate change mitigation and adaption.

Industrial ecology supports companies to become more competitive by improving their environmental performance and strategic planning. It may be used by communities to develop and maintain a sound industrial base and infrastructure without sacrificing the quality of their environments. And it helps government agencies to design policies and regulations that improve environmental protection while building business competitiveness.

The research areas are illustrated by 3 of the current research projects:

1. Sustainable Fish Supply in the Stockholm region

The project aims to improve the sustainability of fish supply in the Stockholm County. To make Stockholm the city of the future – the most attractive city to live in. However, currently, only 2 % of the Stockholm County fish consumption is based on local supply. The project is focussing on five key areas:

1. Creation of a local stakeholder network,
2. Improved governance of natural fish populations,
3. Increased aquaculture with low environmental impact,
4. Education of local administrators and entrepreneurs and
5. Mobilization of consumers and commercial fish supply actors.

The target areas include the main challenges for improved local fish supply in the Stockholm area.

- Improve networking between stakeholders in the region
- Improve fish stock management
- Develop and improve adequate farming techniques
- Initiate dissemination and education of skilled professionals
- Focus on common understandings between producers and consumers

Associated to this project the environmental performance of various farming systems was evaluated. One system, arctic char fed conventional feed, was produced in a fairly small scale in the north of Sweden, while the three remaining systems were viewed upon as possible options to supply Stockholm with fish in the future. Two of these three systems were fed with Baltic Blend which is a new fish feed developed at SLU, Uppsala. The idea of the new feed was to lower the environmental burden by substituting parts of the fish meal with other protein sources such as mussels and microbes. Two of the Swedish systems were recirculating and land-based (RAS).

A life cycle assessment in the study showed that domestic production of fish not necessarily is environmentally preferable but has the potential to be so if some processes can be performed more efficiently. The greatest improvement potential was found in the production of the new feed ingredients, the grow-out phase and the slaughter and guttering of the fish.

The long term aim is to make Stockholm a sustainable society using a philosophic and logistic approach of sustainable development of fish supply and fish stock management.

2. Fish welfare

The project FISHWELFARE aims at identifying key aspects for an ecologically sustainable finfish aquaculture in a Swedish context. This is achieved by evaluating five different methods for current aquaculture fish production concerning

1. their degree of being ecological according to the EU Directive 834/2007 and directive 710/2009,
2. the Swedish KRAV/DEBIO requirements for organic aquaculture and
3. their degree of being ecologically sustainable from a more overarching Industrial Ecology point of view.

The research includes:

- Description, analysis and evaluation of the current EU regulation and Swedish KRAV certification on organic aquaculture production
- Describing five different strategies of fish production:
  1. Norwegian salmon production in cages,
  2. perch cultivation according to the project called ABBORÖS,
  3. pikeperch production in a semi-closed land based system according to Ljusterö lax & gös,
  4. perch production in a totally closed system with combined fish and vegetable production,
  5. organic (KRAV certified) rainbow trout aquaculture by Gustavalax AB, Hagfors Sweden.
- Evaluating the five production chains from
  1. the EU Directive point of view, the Swedish KRAV/DEBIO requirements and
  2. a broader sustainability point of view based on an Industrial Ecology approach.
- Organizing three different workshops with key persons in Swedish aquaculture and where the project results are discussed and analysed
- Elaborate a list of key aspects for a more ecologically sustainable aquaculture that later may be used as a basis for the development of key indicators for sustainable aquaculture

The project aims at providing a comparison of traditional and organic strategies of fish aquaculture from a broad systems point of view and support an improved discussion and decision-making on aquaculture under Swedish conditions. The project output may motivate the Swedish SMEs to start aquaculture in a more ecologically sustainable way which also will have a number of societal benefits:

- Stimulation of local production
- Higher quality products
- Higher food security
- Increased number of work opportunities
- Increased interest in fish products

3. Local produced high quality fish for main capitals – "Närfisk"

The vision of the project is to move aquaculture produced fish closer to the consumers.

The vision is achieved through creation of increased demand of local produced fish and demonstration of the existence of the potential of ecological and profitable production to attract investments.

The project is performed in cooperation between many stakeholders: *Ecoloop*, *KTH*, *SLU*, *Chalmers*, *Länsstyrelsen i Stockholms län*, *Svensk Fiskodling AB*, *Vegafish AB*, *HB Enwe-Fisk*, *Ekomatcentrum*, *Fjärilshuset på Haga*.

The project combines a range of disciplines and competences: Biology, technique, communication including research and development, producers, authorities, consumers.

BF expressed confidence of cooperation between stakeholders in the aquaculture sector. Further BF mentioned a 20 t RAS system outside Stockholm.

A feasibility study 200 t pike-perch farm has been performed and a bank was interested!

BF stressed the need of education and competence and mentioned cooperation between KTH and SLU on aquaculture related course(s).

Stockholm Resilience Centre – Stockholm University

Participants

Max Troell (MT), Associated Professor
Alfred Jokumsen (AJ), MISTRA WGA

Max Troell (MT) is a system ecologist and works as associated professor at the Beijer Institute of Ecology Economics at Stockholm Resilience Centre. MT is theme leader of Governance of coastal and marine systems.

MT is mainly working with environmental problems associated with aquaculture. This work focuses on inter-linkages between aquaculture and fisheries, on different spatial scales. Therefore, the research group does not include core aquaculture research, but its interactions with the ecosystem. At Beijer 1 reseach scientist (docent), 1 post- doc and 1 Ph.D. student is working with aquaculture aspects.

Practical fieldwork has mainly been conducted in developing countries (both tropical and temperate) and involved coastal systems as well as freshwater systems. The studies focus on how aquacultures allocation of low valued fish resources affects poor people's ability to access cheap fish. Focus is much on resources and how aquaculture can increase the socioecological resilience – at regional but also at the global scale.

MT is also interested in developing integrated cultivation techniques, i.e. using seaweeds as biofilters to improve environmental and economic performance.

A current project *Investigate and clarify links and trade-offs between agriculture food production systems, feed resources, food security, and the rapidly growing aquaculture industry*. The underlying question is: Can aquaculture enhance the resilience of global food supply?

MT foresees that the high expansion of aquaculture in China and the increasing domestic consumption of seafood may grip over Global Fish Resources via Aquaculture.

MT mentioned the global paradox that more than 1 billion people do not have enough food and are starving while 3 million people die each year due to obesity. This indicates that food security is complex and not only related to production of more food for the starving people, but also distribution and equity issues.

MT referred to a paper published in Nature: *Solution for a cultivated planet*. It focus' the challenges of simultaneously increasing production and reducing the environmental footprint.

From a holistic approach this may include:

- Reduction of agricultural expansion
- Improving yields and efficiency
- Diversification of system solutions
- Multiple paths (both intensification and intercropping) for efficiency and reduced impacts

- Shifting diets and reducing waste
- Tools is needed for evaluating trade-offs between systems

These aspects may be worth considering in an aquaculture perspective.

MT explained about various global aquaculture systems that may contribute to double the production by 2030 and even shrinking the environmental footprint and improving resilience. The common answer was a "matter of scale". However, it depends on the protection of the biodiversity and the performance of ecosystems that forms the basis for the generation of ecosystem services that are being shaped by social ecological systems.

Compared to other food production (agriculture) systems, aquaculture production is efficient in terms of:

- Yield ton/area
- Nutrient discharge
- Feed conversion
- Energy efficiency

But more focus is needed on technology and new feed ingredients: Vegetable alternatives, micro- and macro-algae, bacteria, fungi, processing waste, other single cell organisms, invertebrates, krill etc.

MT expressed that he had no in depth overview of the aquaculture research in Sweden, but gave the following comments:

- **SLU/UMEÅ** (Centrum för vilt- och fiskforskning) are good at experimental work of farming
- **Mare Novum**, Gothenburg – business innovation and outreach activities
- **SIK – Institutet för Livsmedel och Bioteknik AB** – LCA studies
- **SLU Uppsala/Umeå** – feed development and baltic ecosystem closed loop
- **KTH** – Hållbar fiskförsörjning i Stockholms län + Abborös
- **University of Gothenburg** – life cycles, etc.

As to Swedish aquaculture research in an international context MT found that Sweden may not be visible at the global scale. He asked what the challenges are today and in the future at that scale and how Swedish aquaculture can provide innovative solutions to some of these challenges. Swedish aquaculture also needs to be evaluated from a systems approach and this is currently more being done through ideas about "closing loops", new feed ingredients and siting in water reservoirs.

The perspectives for future aquaculture production in Sweden is dominated by a limiting scope for aquaculture in The Baltic due to restrictions for nutrient discharge and also people's perception of aquaculture activities as pollution and disturbances in the land/sea-scape. Hard competition with e.g. Norway for Salmon production as well as cheap fish from Asia is a challenge to cope with. Instead there may be a scope for niche-markets and sustainably locally grown fish.

Shellfish production should be possible to expand but restrictions due to toxic algae and underdeveloped markets may prevent this at larger scale. MT questioned what was holding back mussel farming development in Sweden historically? There is also a need to change people's perception on seafood production in a longer perspective. Small-scale sustainable farms that are better integrated in the local community and generating additional benefits locally need to be shown as good examples – also generating add-on values for communities in the form of tourism etc. This may give a more positive image of aquaculture as a food production system –

especially if the alternative is to import non-sustainable seafood from e.g. developing countries. The consumers must realize that they have to pay an added-value for seafood that is sustainably produced.

MT identified the needs of specific aquaculture research in the future to include:

- Feed development (alternative resources, waste and by-products)
- Resource efficiency, environmental efficient farming systems
- Comparative analyses of efficiency between animal farming systems, people's perception of aquaculture and food preference
- Comparative sustainability analysis.

Research issues that might contribute to a "boost" of Swedish aquaculture may include studies on consumer preference and how this may be changed, i.e.

- What do the Swedish people want?
- What do they know about their seafood?
- Comparative studies regarding environmental performance – locally and globally
- Communicating imported food's environmental and social footprint

Connected to this MT also found that the results from studies on consumer preferences/local acceptance as well as experiences from large-scale cases might be reflected in the aquaculture production.

The invested research money should preferably be reflected in a growing non-subsidized aquaculture industry.

The reasons for the stagnant Swedish aquaculture production may be due to:

- Environmental legislations limiting scale of production (if some at all)
- Strong competition (Norway, Asia)
- Limited investments/risks (no oil industry backing up)
- Question mark the stagnating Swedish mussel industry – Toxic blooms? – Investments? – European competition?

Further, MT put the following comments related to a future food supply from Swedish aquaculture:

- Focus the economic support to Swedish aquaculture compared to the profits/benefits in comparison with agricultural support
- A few big farms (>100 tonnes/year) represent about 95 % of the production – i.e. economic feasibility for small farms?
- How can Sweden contribute to the increased global seafood demand? – Can it be a main player? – Focus on Swedish consumers? – Europe?
- Hydro power lakes – seems like a possibility for production! But not to include all lakes that are oligotrophic. What does the Water Frame Directive say?
- Replacement (compensation) of wild fish by farmed fish (restocking) – genetic quality and performance?
- Baltic and West coast – problematic for working towards "Good water status" (BSAP)
- *Matlandet* – seems to be most focused on "tasty and healthy" food – instead of ecological (and ethical) considerations

- "Minimum environmental impact" – difficult to define what this is. What is accepted?
- Algae production for human consumption – a challenge – which algae sp., nutritional quality, costs, etc.
- Need incentives for extractive species (mussels, seaweed). Economic?
- Mussels as fish feed/mussel meal? Large scale/volumes? Cost?
- Expanding in lakes (and coasts) – how do the public look on this?
- How to make sustainable aquaculture a part of the land/seascape. Is agriculture a sustainable part of the landscape? Effects on biodiversity, Ecosystem services, etc.
- EFF and other structure funding – how profitable is aquaculture in Sweden?
- Without support?
- An objective is "A net contribution to food supply" – how to define this? What scale?
- Mussels – N+P removed at a regional scale – but local accumulation! How to find a good balance?
- Temporary storage of mussels on deeper water (detoxification) – interesting. How can this be done? Learning from Norway?
- Perch – 45% fishmeal!! Is this a suitable species to farm?
- Sweden developing its own certification system? Why not adopting existing? ASC?

Ministry of Rural Affairs

Participants

From the Ministry
State Secretary *Magnus Kindbom* (MK)
Political officer *Charlotte Erichsson* (CE)
Scientific officer *Johan Andersson Arnell* (JAA)

From MISTRA
Axel Wenblad (AW), MISTRA WGA
Alfred Jokumsen (AJ), MISTRA WGA

In the presentation of the MISTRA task given to the working group AJ pointed out, that a recommendation to MISTRA to invest in aquaculture could be linked to a commitment from the Swedish government to concrete back up of this potential investment.

Magnus Kindbom (MK) expressed a positive will from the government to support aquaculture production. MK mentioned explicitly Arctic char, perch, pike-pike-perch and mussels.

He also paid attention to the output of the flagship project AQUABEST.

AW expressed concern about the mussel farming in the west coastal zone and the local opposition against the 300 m dispensation distance to the coast. JAA replied that the ministry has acknowledged the problem and initiatives had been taken to address it. They would take these concerns forward to the evaluation of the regulations that have been initiated by the Government.

MK also pointed out on-going efforts to simplify the different legislations related to aquaculture, including adjustment of monitoring fees to a more compara-

tive level to similar food production (agriculture). He also mentioned some dispute about ways of calculation discharges from aquaculture (models).

AJ drew the attention to the wording "hazardous production" about aquaculture in the Swedish environmental legislation, which AJ perceived an inappropriate wording to reflect the aquaculture production sector. MK replied that he had not been presented for scientific documentation for changing this characteristic of Swedish aquaculture production in the environmental legislation.

The Board of Agriculture has got a significant role in the management of aquaculture and is expected to be "the one door" for the farmers to deal with in relation to permissions, supervisions/inspections.

AJ asked about the EFF and how resources were allocated to fisheries and aquaculture. MK answered, that a certain amount has been allocated to aquaculture (cf. SOU 2009: 26), but the main part had been allocated to fisheries and especially scrapping of fishing vessels. However, by the new period of the EMFF program 2013 → 2020 MK anticipated that aquaculture would be given higher priority to this program.

MK mentioned that the ministry had fulfilled their obligation in the strategy to establish a National Aquaculture Council through Board of Agriculture.

AJ stressed the need of a medium level education and training of staff at fish farm administrations and inspections, farm assistants etc. It was his impression from the interviews, that missing knowledge about practical fish farming was one main reason for the current challenging and inappropriate administration of the aquaculture production. AJ asked whether the government might support this education by funding to the relevant institutes responsible for the education. MK replied that this was currently not possible.

AW suggested that the government might also support aquaculture indirectly by requesting f. ex. FORMAS to allocate a certain amount of their annual funds to aquaculture (f. ex. of the new SEK 50 million). MK and the ministry would take this aspect into consideration.

We got no concrete promises, which hardly might be expected at this stage. But the State Secretary and his officers listened and made notes and their approach was positive and they expressed will to assist and facilitate the process of stimulating aquaculture in Sweden.

The National Veterinary Institute (SVA)

Participants

Ph.D. *Eva Jansson* (EJ)
Research engineer *Anders Hellström* (AH)
Senior Veterinary Officer *Thomas Nilsson* (TN), MISTRA
Alfred Jokumsen (AJ), MISTRA WGA

The National Veterinary Institute – Statens Veterinärmedicinska Anstalt (SVA), is a national authority within the Swedish ministry for rural affairs within the areas of animal and human health, good environmental and sustainable food production. SVA is the only public veterinary laboratory in Sweden.

The most important role of the National Veterinary Institute, SVA, is to align the activities towards contagious and other serious infectious diseases of animals that imply a threat to supplies of animal foodstuffs that lead to losses for the production of animals that may involve diseases that can be transferred to humans. Diagnostic capacity for the most feared contagious animal diseases is available at SVA. About 500 persons are employed at SVA.

EJ and AH are working at Department of Animal Health and Antimicrobial Strategies – Section of Fish and Shellfish (SFS). The section deals with disease surveil-

lance, precautions for exotic diseases, diagnostics, knowledge transfer, research and development.

The activities at SFS include:

- Diagnostic laboratory for fish and shellfish – farmed, wild, ornamental or intended for research
- National reference laboratory for all notifiable diseases in fish and shellfish
- Experts in matters on:
  - Emerging diseases
  - Investigation of transmission routes
  - Establishing decontamination plans
  - Import/quarantines
  - Technical constructions of fish farms in relation to health protection
  - Movement of fish

The following statistics on Swedish aquaculture were presented:

The statistics included 248 farms, producing 8,708 tonnes. 41 farms produced < 5 t., 93 farms produced 5 -100 t., and 28 farms produced >100 t.

The farmed species included (number of farms in brackets):

- Rainbow trout (110)
- Atlantic salmon (23)
- Other salmonids (104)
- Carp (1)
- Eel (1)
- Other freshwater sp. (8)
- Other marine sp. (1)
- Crayfish (33)
- Mussels (14)
- Oyster (1)

In addition 754 t of fish were produced for angling and 289 t for restocking wild populations.

The farms are distributed mostly all over Sweden, but particularly south of a horizontal line across the country from Stockholm.

As a national reference laboratory SFS is much involved in the National Health Control. However, the owner of the National Health Control Program is the Board of Agriculture (BA), but since about 20 years ago the responsibility for the practical running of the program has been delegated to the Fish Health (FH) AB, which is the industry's own health organization. In 2010 BA realized the inappropriateness of the industry sampling by themselves – and it is currently being planned that SVA will take over the role of organizing the sampling.

The Health Control Program includes:

- Monitoring to maintain Sweden's approved zone-status for: VHS, IHN and SVC
- Monitoring Swedens guaranties for: IPN in continental zone, Bonamia ostreae Marteilia refringens
- Approved control program for: IPN in coastal zone and BKD in continental zone

The Swedish Fish Health Control has organized a voluntary health control program for the farmers, which includes:

- 60–85 % of all fish farms
- Inspection during the summer with a water temperature > 14 oC
- Sampling of material for diagnostic purposes in case of symptoms
- Hygienic advisory
- Farms with a breeding program are sampled every year for virus and BKD
- Focus on endemic diseases

AH and EJ explained that the farms are monitored twice per year by the district veterinarian (employed by the Board of Aquaculture).

The health control of wild fish and shellfish populations includes:

- Yearly sampling of wild brood fish (salmon & brown trout) for national fisheries and free living blue mussels and oyster intended for harvesting
- Occasionally in connection with high mortality or prevalence of disease symptoms in a water area

Eggs from wild fish are tested and only disease free eggs are used. Brood stock is discarded.

The institute is working to obtain funding to be able to conduct regular surveys of key species in specific water areas.

AJ and EJ found that an increased Swedish aquaculture production would imply the need of improved effectiveness and competence of national as well as regional authorities, but also further cooperation within the aquaculture industry, including effective marketing and sales initiatives. And finally a mutual trustful cooperation between producers and the authorities would certainly facilitate the development.

Fish diseases are still a major challenge in aquaculture and cooperation especially between the Nordic countries in the development of new diagnostic techniques as well as measures for prophylaxis is called upon. The global trade of ornamental fish highlights the need for international cooperation for development of systems for control and information about emerging diseases. It is important to follow the sensitivity to antibiotics in aquaculture and to harmonize techniques to compare the situation in different countries. Studies on immune functions in fish for development of methods to evaluate the effects of functional vaccines are demanded.

AH and EJ exemplified their views about the future of aquaculture in Sweden:

- A large potential for expansion, both in terms of number of farms and production in tonnes exists including the unique Swedish opportunity to produce specific pathogen free fish for consumption, restocking and fisheries
- Farms located in nutrient-poor hydroelectric power dams combined with feed production from fish from the Baltic Sea (environmental aspect)
- Due to competition from Norway niche species may be more profitable (e.g. char)
- Farming in recirculation systems (environmental as well as health protection)
- Future focus on:
  - Large farms (> 100 tonnes)
  - Farming alternative niche species (e.g. perch, pike-perch, sturgeon etc.)
  - Using of excess energy from industries and culture warm water species (e.g. tilapia, catfish and giant prawns – prepare for climate change)
  - Organic production

However, increased production and maybe new species recalls attention to health risks:

- Bigger farms make greater risks of impact of diseases both in the farm and the environment
- Free trade of fish and eggs inside EU, combined with import from 3rd countries, increases the risk of spread of (for Sweden) exotic diseases
- Global trade of ornamental fish
- The economic situation for aquaculture is becoming increasingly difficult, which often reduces the ambition for disease control in the farms
- Antibiotic resistance
- Cultivation of "new" species starts without any study of diseases and health protection
- Climate change resulting in a higher water temperature will give a different disease panorama in aquaculture and also provide a basis for an increased number of disease agents

AH and EJ provided a list of research projects (including cooperation links, financing):

- Parasite infection, protista inf. in perch, Perca fluviatilis – KSLA
- Francisella noatunensis in wild cod – Hjärrefonden
- Marteilia refringens in blue mussel – Board of Agriculture
- Development of a database for fish virus – Epizone WP 6.1
- Epizone WP 6.1: Surveillance and epidemiology of emerging viral diseases in aquaculture
- Epizone WP4.1 Emerging disease: Koi Hepes virus serology for detection of Koi herpes virus
- Development of molecular genetic techniques to characterize isolates of Flavobacterium psychrophilum
- PCR method for:
  - White Spot disease in crustacean
  - Parasites in group Myx ozoa
  - Marteilios (Marteilia refringens) in blue mussel
  - Herpesvirus in oysters
- Epizootic Ulcerative syndrome (EUS), "Red spot disease – CoVetLab (Collaborating Veterinary Laboratories)
- Surveillance and Epidemiology of emerging viral diseases in aquaculture – Epizone WP 6.1
- Development of immunological diagnostics methods for fish – Lundströms stiftelse
- Mycobacterial infections in ornamental fish – Board of Agriculture
- Epizootic Ulcerative syndrome (EUS), "Red spot disease – CoVetLab (Collaborating Veterinary Laboratories)
- Surveillance and Epidemiology of emerging viral diseases in aquaculture – Epizone WP 6.1

- Development of immunological diagnostics methods for fish – Lundströms stiftelse
- Geographical survey of presence of Parasitic Kidney Disease – Board of Fisheries
- Diagnostics of suspected crayfish plague – The Swedish Agency for Marine and Water Management

AH and EJ called for a common and multidisciplinary approach to the aquaculture research needed in Sweden, i.e. collaborations between the Board of Agriculture/Jordbruksverket, The Swedish Agency for Marine and Water Management/HaV, Swedish University of Agricultural Sciences/SLU, National Veterinary Institute/SVA, County councils and the Fish Health Service was supposed to improve research efforts and output.

AH and EJ listed the need of research from SVA point of view:

- Diagnostic methods for
  - Virus (VHS, IHN, SVC, KHV) and BKD that do not involve sacrificing the animal (Better acceptance from the farmers and more economic)
  - Emerging diseases (Health protection)
- Diagnostics, prophylaxis and therapy:
  - Of blue mussels and oysters
  - For "production diseases" eg. Flavobacterium sp.
  - Of health problems associated with the introduction of "new" species for farming
  - Better economy, more effective health protection, animal welfare
- Screening
  - Important diseases in wild populations (Franscicella in cod, herpesvirus in eel, gaffkemia in lobster etc) – important in relation to location and construction of farms as well as preservation of species
  - Resistance to antibiotics – human aspects and health protection
  - Survey in wild/farmed/ornamental fish (and shellfish)
  - Survey in staff handling live fish
  - Development of a common EU method for determining resistance VetMIC®
- Fish for research
  - Control program/procedures for determining health status – reliable results
  - Ethical guidelines – welfare
- Ornamental fish and crustacean – presence of:
  - Zoonotic agents / Epizootic agents – Human aspects and health protection

EJ presented an evaluation of diagnostic methods. She used Bacterial Kidney Disease (BKD) as an example, a disease with no therapy or no functional vaccines available. The only control method currently available is regular screening programs and avoidance. The key issue is therefore diagnostic methods with high sensitivity.

Precautions also have to be taken to prevent disease transmission between wild fish and farmed fish.

Farming oysters are being challenged by low survival among oyster larvae. Though the survival has recently been improved the reasons for the high mortality is unknown.

EJ explained their activities on assessment, risk-analysis and giving recommendations for avoidance of fish – and shellfish borne diseases caused by bacteria,

parasites or virus. Specific risks are challenged by consumption of raw or undercooked fish and shell- fish or dermal contact with infected fish or water. People at risk are consumers and people handling fish (fish-farmers and staff, fishermen, aquaculture processing plants, handling ornamental fish a. o.)

SFS are also testing sensitivity to antimicrobial substances and resistance.

AH and EJ stressed the need for better education and training of people working in the aquaculture industry. SVA run voluntary courses for regional veterinarians and they are aiming courses for fish farmers. However, farmers do not pay sufficient attention to diseases even though the district veterinarians are very ambitious. Need of improved communication and common understanding between SVA and the farmers organisation to justify the SVA responsibility and expertise in fish health.

World Wild Fund for Nature (WWF) – Sweden

Participants

Senior Conservation Officer, Act. Dir. Mar. & Freshwater *Inger Näslund* (IN)
Conservation Officer Fisheries and Marine *Charlotta Järnmark* (CJ)
Thomas Nilsson (TN), MISTRA
Alfred Jokumsen (AJ), MISTRA WGA

World Wide Fund for Nature – **World Wildlife Foundation** (WWF) was established in 1961 and operates in more than 100 countries. WWF currently funds around 2,000 conservation projects globally and employs almost 4,000 people across the planet. WWF is versatile being present from the local to the global level dealing with species conservation in e.g. central African rainforests, through to face-to-face discussions with institutions such as the World Bank and the European Commission.

The work of WWF is dependent on funding from globally more than 5 million supporters.

The mission of WWF is to:

- Conserve the world's biological diversity
- Ensure sustainable use of renewable natural resources
- Promote reduction of pollution and wasteful consumption

The Swedish branch of WWF was founded in 1971 to support the international operations of WWF as well as Swedish research, education and practical nature conservation work. WWF Sweden is organized with a council of about 50 people where HM the King of Sweden Carl XVI Gustaf is the president. Currently WWF Sweden is focusing on: Forests, Climate, Baltic Sea and Marine areas, Cultural landscapes and Education & Youth. WWF has the ambition to contribute to make Sweden become a world leader of climate-smart energy solutions.

Inger Näslund (IN) has a background as marine biologist and has been working for-WWF since 10 years. She is currently acting director of SW & FW unit.

Charlotta Järnmark (CJ) has a M.Sc. in marine systems ecology. CJ currently handle market issues and consumer advice on seafood in Sweden, including development of the WWF food guide *Fisk till middag* and certification issues.

WWF has a positive approach to aquaculture producing sustainably while safeguarding biodiversity and low environmental impact, i.e. precautionary and ecosystem based aquaculture. A sustainable aquaculture will have low carbon footprint, low freshwater and minimal land use as well as low negative environmental impacts and

research is needed to facilitate this development. However, market analyses on the demands of the consumers as well as risk analysis regarding adaption to climate change and environmental footprint should also be considered.

WWF is concerned about the commercialization of juvenile non-hatchery fish for aquaculture, e.g. glass eels and use of fish meal from discards and by-catch for aquaculture feed as WWF envisage a risk to the health of fish stocks and of the entire marine ecosystem. WWF encourages development of ecologically sustainable alternatives to fish meal and fish oil.

IN and CJ stressed that aquaculture needs an improved image and credibility among the public, including government awareness and consumer acceptance. IN and CJ mentioned the Global Aquaculture Dialogues, where WWF has been putting great efforts in working with all the stakeholders including producers, retailers and NGO's to develop a set of transparent standards that reflect world's best practice in environmental management of fish and shellfish farming. Recently the standards on FW trout farming were finished and these standards now represent a comprehensive collection of global best environmental management practice. WWF believes that adoption of an independent certification scheme will provide more credibility and allow for reductions in the "Food guide" red tape as the standard will ensure best practice management.

The global standards for responsible aquaculture are managed by Aquaculture Stewardship Council (ASC). ASC is an independent non-profit organisation that was founded in 2010 by WWF and IDH (Dutch Sustainable Trade Initiative) to manage the dialogue standards.

CJ drew the attention to a study of Sumaila et al., 2010 (J. Bioeconomics 12, 201-225): A bottom-up re-estimation of global fisheries subsidies. The study showed that quite large amounts of governmental subsidies are supporting global fisheries and there by supporting overcapacity and overfishing. The message from the publication is that by re-allocating this subsidy money to create new jobs, infrastructure, improve local socioeconomic conditions and improve fisheries management (re-building stocks) might an ecosystem managed fishery be achieved which in the long term would be more profitable and sustainable.

As to the development of Swedish aquaculture IN and CJ raised the following issues:

- Concerned about the marine fish resource (fish meal and – oil) and farming carnivorous fish
- Sustainable aquaculture feeds, LCA, C-footprint
- Farming in the oligotrophic power dams – cold water – slow growth
- Society aspects – market analyses. Do not compete with Norway
- Recirculation technology (RAS) – Definition of degree of recirculation
- Regional development – Be specific on sustainability
- Selected species – Niche production
- Education and training of skilled professionals
- Ecosystem based management

Annex 2. Hearing with stakeholders

NOTES
MISTRA Hearing on Aquaculture Research
8 January 2013
Stockholm City Conference Centre, Norra Latin

Welcome and Background – Thomas Nilsson, TN

About 30–35 persons participated in the hearing (cf. participant list).

TN welcomed the participants. Unfortunately Executive Director MISTRA Lars-Erik Liljelund had become ill and could not participate. TN gave a background of MISTRA, the Working group on Aquaculture and Terms of Reference.

Why should Sweden have aquaculture? – Ole Torrissen, OT

OT started his presentation by changing the title to: *Should Sweden have aquaculture?* to be even more provocative. OT mentioned that the Norwegian export to Sweden was 72,000 tons (2011) of mostly salmon, which raised the question why not producing these fish in Sweden?

OT added that it was important for Sweden to focus on food security and employment. In the perspective that aquaculture is much more feed efficient in producing food compared to terrestrial production (agriculture) and due to the fact that Sweden has huge water resources available as well as technology, Sweden has the potential to increase their share of the aquatic food supply and create new jobs. OT called for looking upon possibilities and focused research in selected areas of aquaculture.

WWF's view on aquaculture in Sweden – Inger Näslund, IN (WWF)

IN stated that aquaculture was an import business to secure food supply due to the declining wild fish stocks.

However, for the development of Swedish aquaculture IN stressed the importance of responsibility/traceability/transparency/reduced footprint/ certification along the whole value chain from the producer to the consumer with the aim of achieving sustainability and balance/resilience of ecosystems/biodiversity and socio-economy.

Preliminary analyses and conclusions by the Working Group – Alfred Jokumsen, AJO

AJO briefly outlined the work performed in the WG and ended up with the identified three research themes to be proposed for a potential MISTRA research programme:

- Global ecosystem aspects
- Environmental efficient production
- Policy instruments

Questions and general discussion

The proposed themes were generally assessed relevant from the audience and seemed to contribute to a niche for "Sweden to make a difference". However, there were comments on potential outcome, profitability of business' and connection between research and entrepreneurs, food security, bureaucracy, but all the comments have been taking into account in WG discussions and the report.

Outcome of discussions in breakout groups

The participants were divided into three groups, which were asked four questions to be discussed and reported for each theme (1 theme per group).

The questions were:

1. **Why is this theme important?**
2. **Main challenges and possible solutions?**
3. **Which are the main issues that this research theme should address? Possible headlines for research activities?**
4. **How to disseminate research results? How can the results be applied?**

GROUP 1: Global ecosystems aspects

1. This theme is important as EU would like to include new species to diversify the aquaculture production. Development of new species will give opportunities for new aquaculture business where currently available species are not appropriate. With new species, new sites may become appropriate for aquaculture. New species can also give opportunities for multispecies or integrated farming. Multispecies farming requires new knowledge in all parts of the value chain, from breeding to selling.

   MISTRA should focus on species naturally occurring in Sweden since import of new species increases the risks of introduction and spreading of diseases from exotic species.

   Because new breeding programs are very expensive and time consuming, focus should be on local species demanded on the market (by the consumers).

2. As to main challenges and possible solutions development of new species demands research in several fields that must be integrated. Socioeconomic aspects must also be included. The benefit for the society is an important aspect.

   The cycles of carbon, nitrogen and phosphorus are important parameters in Swedish aquaculture. Especially P is an asset and the cycle must be closed and have a short circulation time for an efficient and ecologically sustainable utilization of the resources. This can be achieved by using recirculation systems or through the AQUABEST model. The AQUABEST model is based on a combination of fish farms in oligotrophic hydropower dams with mussel farms in the southern Baltic Sea. The mussel farms will function as C, N and P sources from which fish feed can be produced for fish farming in the dams.

   More research is needed for clarification of the effects of both the fish farms and the mussel farms, especially a dynamic modeling of the ecosystems from the hydropower dams to the mussel farms.

   More research is also needed regarding feed. What more than mussels from the Baltic Sea can be used as fish feed?

   Another important aspect of feed research is not to increase the nutrient load to the Baltic Sea due to import of C, N and P from other parts of the world. The Baltic Sea region, and especially the Baltic Sea, must be the source from where we get the raw material for feed. In this way we will decrease the eutrophication.

3. Main issues of research to be addressed. Headlines for research activities.

- Development of new feed types that will reduce import of nutrients from outside the BSR
- The quality of new feed types/ingredients must be secured, especially for "feed mussels"
- The production systems must be improved to reduce the environmental impact
- Modeling and environmental systems analyses which monitors the effects of aquaculture
- The research should have a holistic approach: Feed – the cultivated species – production – the market – the environment
- New marine species for cultivation that will function in recirculation systems
- The research should have a long term perspective and be integrated.

4. Dissemination and application of research results.

- Integrated research will automatically lead to a better chance of implementation of the results
- It is important that there are active actors/stakeholders from both business and society

GROUP 2: Environmental efficient production

1. This theme is important because:

- It is a key issue in the development of Swedish aquaculture
- Fish and shellfish is an important food source
- If Sweden wants to have an influence on aquaculture products, there has to be a Swedish production
- MISTRA is one of few actors that have the real muscles to help Swedish aquaculture become a sustainable and economical profitable production
- Exporting Swedish aquaculture as a concept, regarding sustainability for example, is a good way to help develop the production
- The "right" kind of aquaculture can improve the environmental status (e.g. mussels)

2. a) Main challenges:

- There is no general solution, so to get the most out of the research, it should be concentrated on a few species
- The sustainability and the quality of feed
- Investment and finance, there is a large gap between "hobby" and an economic profitable production
- Optimize the size of the production
- Getting new entrepreneurs into the business of aquaculture, especially in urban areas
- The balance between carbon and nitrogen in de-nitrification system
- Disease control in multitrophic systems
- Nutrient efficiency
- Optimize an multitrophic system and adjust the product to the market

b) Possible solutions:

- Development of new feed raw materials
- New techniques
- Traceability
- Local produced products

- Higher value in the landscape
- Socio-economic development
- Positive environmental effects

3. Main issues of research to be addressed. Headlines for research activities.
   - Feed raw materials
   - Multitrophic system, both biological and technical
   - Niched species and locally suitable and production techniques
   - Closed systems
   - Traceability markers for the whole chain, from the beginning and back again
   - Animal welfare and the ethics of the production – measurable indicators
   - Resilience in the system, regarding immune system etc.
   - The market, consumer perception, economical profitability
   - LCA, comparison between different systems
4. Dissemination and application of research results.
   - Connection between the researchers, producers and the education system
   - The education should be directed to all the stakeholders of the information
   - Involve the producers early in the research program
   - Have a short term perspective to help the investment process
   - Construct a plan how to apply the results from the start
   - Make sure there is a possible infrastructure for new species, breeding and selection
   - Have a plan how to take care of the products and raw materials from the production – product development

GROUP 3: POLICY INSTRUMENTS

The research theme included: Legislation – Economic incentives – Socio economic dimension – Labelling/certification – Organic farming.

1. This theme is important because the policy framework and regulations (both national and EU) are basic to the development of any business like aquaculture. There are several EU directives with connection to aquaculture legislation, e.g. Council Directive 2006/88/EC:

http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32006L0088:EN:NOT

http://www.ecasatoolbox.org.uk/the-toolbox/indicator-groups/International%20regulations/int_reg.pdf

A weakness for a successful Swedish aquaculture is the need of knowledge at all societal levels. There is a need for education of fish farmers, authority personal giving permission to the establishment of farms, fish/shellfish/molluscs health inspectors, authorities. Clear rules for getting permit to establish a farm is needed as well as spatial planning, i.e. clear rules for selection of suitable sites for establishment of farms. This may also stimulate entrepreneurship.

There is also a need of information for the consumers, to let them explore the quality of nearby produced fish/shellfish/molluscs. A tool might be social learning; i.e. transformation/change of society/communities through education for sustainable development.

There is a big gap between people in the urban areas and the food producing sector. It is important to find routes for an efficient transfer of knowledge from the researchers to the farmers. Aquaculture is still a relatively "new area" where financiers have difficulties in making risk analyses, and hence limit the economic incentives to aquaculture development.

Finally the group identified a need for historical information about meteorological parameters in lakes and coastal areas.

2. As to main challenges and possible solutions the group identified encouragement of consumers for buying products produced in aquaculture: fish/shellfish/molluscs. Further education, link between business and the research, stimulation/economic incentives of entrepreneurs and facilitation of establishment of new fish farms is crucial for a positive development of aquaculture in Sweden.

3. Main issues of research to be addressed. Headlines for research activities.
   - Information projects about how to stimulate consumers by a social learning theory concept: People learn by observations/ influences of others. Improve knowledge about the water resource/environment and society
   - Development of co-management systems: Development of models with a contextual perspective taken into account economic aspects, effectiveness of management, decentralization and local authorities for sustainability and more effective management
   - Aquaculture within the framework of the water framework directive (WFD), how to bring in user perspectives in the WFD management
   - Economic conditions
   - Crossroad options: Net-pens along the coast – extensive farming in lakes – intensive closed farming (RAS) – Integrated systems (systems perspective).

4. Dissemination and application of research results are included above.

After the workshop/hearing the WG met to evaluate the event. The overall evaluation was positive. The feedback from the participants reflected the content of the three main themes presented by the WG to be those the WG intends to advice MISTRA to address in case the Board of MISTRA decides to invest in aquaculture research.

Specifically the following main messages were extracted from the hearing:

Global ecosystems aspects

The theme was assessed important due to the vision of EU to diversify European aquaculture production. However, only naturally occurring species in Sweden were preferred as to minimize the risks of introduction of contagious diseases from imported foreign species. The use of existing species was further supported by the breeding progress already achieved with e.g. Char.

The input to the question on main challenges and possible solutions to aquaculture development mainly focused on environment issues, i.e. concerns about the Baltic Sea, recirculation of N, P and C; RAS and integrated aquaculture production, i.e. mussel farming, catching of nutrients and ecosystem dynamics as well as socio-economic aspects.

The main issues of research to be addressed included long term and integrated research with a holistic approach, i.e. production systems – cultivated species – feed – environment – marketing – society.

For the dissemination and application of the research results a close connection and cooperation between stakeholders along the whole chain from producers to consumers was important.

Environmental efficient production

This theme was stated to be important as it was assessed as the only way of developing sustainable Swedish aquaculture and that it might imply a win-win situation of Sweden becoming exporter of new concepts and technologies within environmental efficient aquaculture production.

The main challenges were assessed to be both economic and technical. The technology of environmental efficient production requires a certain production volume to be economic profitable. The technological challenges might be solved (high quality feeds, RAS technology and management), but a bigger challenge was to get new entrepreneurs into the business (especially in urban areas), i.e. investment and finance (investors are reluctant/cautious maybe due to low knowledge about aquaculture).

The main issues of research to be addressed included recirculation technology and multitrophic systems, Life Cycle Analysis (LCA) and comparison and resilience of the systems, traceability, welfare and ethics.

For the dissemination and application of the research results a close connection and cooperation between stakeholders including education and training along the whole chain from producers to consumers was assessed as important. The end-users should be involved early in the project planning process.

Policy instruments

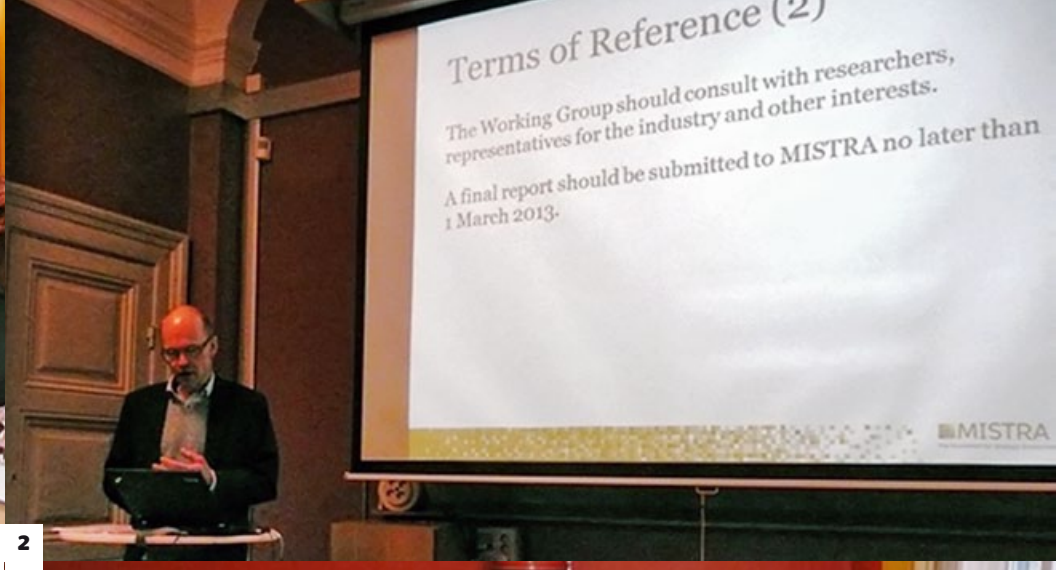
The theme was assessed important because the policy framework and regulations (both national and EU) are basic to the development of any business like aquaculture. Clear rules for getting permit to establish a farm is needed as well as spatial planning.

There is a need for education of fish farmers, authority personal giving permission to the establishment of aquaculture. Improved interaction between research and business and improved information about aquaculture to the society in general and in particular the financing sector.

Main issues of research to be addressed included targeted information projects, co- management (holistic) systems, spatial planning.

Pictures from the hearing

See next page.



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1 & 3 Views of the audience.

2 Thomas Nilsson presented the background and ToR of the Working Group.

4 Alfred Jokumsen presented preliminary analyses and conclusions by the WG.

5 Discussions in one of the three breakout groups.

6 Axel Wenblad was moderator.

4 6

5

Oceans cover more than 70 % of our planet. While plant production in the sea is at the same magnitude as the terrestrial plant production, we get only slightly above 1 % of our daily energy intake from sea food. The reasons for this disparity are multiple. However, the low utilization of marine resources opens huge potentials for increased food production through cultivation of the oceans. This may substantially contribute to closing the gap in food supply caused by increasing world population and prosperity.

This report elaborates on how Swedish aquaculture industry can develop into a green business producing environmentally sustainable healthy food and how research can contribute to such a development.

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